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Field Investigation of Contaminant Loss from Chemically Stabilized Industrial Sludges

(U.S.) Army Engineer Waterways Experiment Station, Vicksburg, MS

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FIELD INVESTIGATION OF CONTAMINANT LOSS FROM CHEMICALLY STABILIZED INDUSTRIAL SLUDGES

by

Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
Vicksburg, Mississippi 39180

Interagency Agreement No. EPA-IAG-D4-0569

Project Officer

Robert E. Landreth
Solid and Hazardous Waste Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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Four sites where stabilized industrial wastes had been disposed were examined to determine the effects of stabilized wastes on surrounding soils and groundwater. All areas selected for study were in the humid eastern or southern United States where rainfall was sufficient to produce abundant leachate. The sludges had all been fixed using the same proprietory process involving addition of cementitious materials to form a stable, soil-like product. Two of the industrial waste sites contained auto assembly (metal finishing) wastes, one site contained electroplating wastes and the fourth site contained refinery sludges. A randomization procedure was used to determine if consistent significant differences existed between samples from under and outside the waste disposal area.

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report presents results from the field investigations of four industrial waste disposal sites to determine their effects on surrounding soils and groundwaters. It provides basic data on the potential pollution from land disposal of industrial waste and will add to the knowledge required to determine the environmental consequences of the land as a receiver of waste materials.

FRANCIS T. MAYO, Director
Municipal Environmental
Research Laboratory

ABSTRACT

Four sites where stabilized industrial wastes had been disposed were examined to determine the effects of stabilized wastes on surrounding soils and groundwater. All areas selected for study were in the humid eastern or southern United States where rainfall was sufficient to produce abundant leachate. The sludges had all been fixed using the same proprietory process involving addition of cementitious materials to form a stable, soil-like pro--uct. Two of the industrial waste sites contained auto assembly (metal finishing) wastes, one site contained electroplating wastes and the fourth site contained refinery sludges. A randomization procedure was used to determine if consistent significant differences existed between samples from under and outside the waste disposal area.

The physical properties of soils under the disposal sites were effected little, if at all, by the disposal operation. No major changes in soil dry density, water content, hydraulic conductivity or percent fines could be detected.

At one of the auto assembly waste disposal sites, high background levels of constituents in the groundwater masked any escape of pollutants from the fixed sludge. Elevated levels of chloride, calcium and sodium were found in groundwater under and down the groundwater gradient from the disposal area at the second auto assembly plant. Only elevated levels of sulfate and boron were found under and down the groundwater gradient from the electroplating waste site. Elevated levels of sulfite, nitrite, cyanide, phenols, and arsenic were noted in groundwater under and down dip from the disposal area at the refinery site. Toxic metal contamination in groundwater was not a serious pollution problem at the sites studied at the time of the survey.

Soils beneath treated auto assembly wastes disposed at two locations showed elevated levels of manganese, sodium, and selenium. Soils beneath treated electroplating waste showed elevated levels of iron, sodium, mercury, and nickel. At one location where treated oil refinery waste was disposed no significant soil contamination was detected. Even in contaminated soils the levels of constituents determined were well within the ranges reported for natural soils.

Distilled water extracts of soils collected beneath the stabilized wastes and at comparable elevations outside the site showed appreciable contrasts in chemical composition. Some potential pollutants were present in consistently larger quantities in extracts from sub-waste soils. Chromium, lead and selenium were found in some extracts at levels above those considered acceptable for public drinking water supplies. The high levels of potential pollutants in distilled water extracts suggests contaminants from the waste could be leaching into the groundwater.

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SECTION 1

INTRODUCTION

Fifty-seven million metric tons (approximately 125 billion pounds) of hazardous waste are produced annually in the United States. Much of this material is landfilled because other disposal methods are not applicable and reuse at present is impractical (1). For many of these wastes, solidification/stabilization may greatly reduce the potential hazard associated with landfilling yet permit future reclamation.

A recent EPA-funded survey of 50 land disposal sites containing large volumes of industrial wastes revealed that 43 of the dumps, landfills, or disposal lagoons had caused degradation of groundwater quality (2). Selenium, copper, barium, cyanide and nickel were the most frequently occurring inorganic contaminants. Excessive amounts of arsenic, chromium and lead were also common. Hazardous inorganic substances exceeded Federal drinking water standards at 26 of the sites.

Careless disposal of toxic industrial wastes can cause severe degradation of groundwater quality. At Alma, Michigan, the disposal of refinery wastes in a shallow aquifer resulted in the condemnation of two water-supply wells due to contamination by phenols (3). Sludges containing paint residue were buried in a Maryland sand and gravel pit causing local groundwater contamination by hexavalent chromium (7.2 mg/liter) (4). Similar contamination of wells in Nassau County, New York, caused well closings due to contaminants leached from electroplating wastes. Many other examples can be cited.

This report is the third and final one of a series concerning the effects of leachate from waste disposal sites on the surrounding soil and groundwater systems. Municipal landfills (5) and flue gas cleaning waste landfills (6) were the subjects of the first two reports. Each of the studies includes the results of soil and groundwater analyses for boreholes samples taken within and outside the boundary of the disposal site. This study similarly includes an investigation of soil, groundwater, and analyses of the stabilized sludges. Soil samples were tested physically and distilled water extracts and nitric acid digests of the soils were analyzed chemically. Groundwater and stabilized sludge samples were analyzed chemically.

The stabilization of industrial wastes to prevent or retard the leaching of contaminants by percolating water was evaluated at four sites. Sites containing stabilized metal finishing, electroplating and refinery wastes were selected due to the need for treatment of these waste types throughout industry. Some of the data presented in this report have appeared in earlier

research reports. A summary of the results of the investigation of physical properties of the soils at these sites and the chemical quality of groundwater under and around these sites was presented in ref. 7. An evaluation of soil contamination levels under the four sites was presented in ref. 8. This report was prepared to bring all of the data together under one cover and produce an overall evaluation.

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SECTION 2

CONCLUSIONS

At the four sites where chemically stabilized industrial waste had been deposited no consistent physical changes could be detected in the soils beneath the landfilled wastes. None of the expected physical effects of disposal such as decreased permeability or increased fines in the sub-waste soils could be observed using standard testing procedures.

Changes in groundwater quality that could be related to the waste disposal activities could be observed at three of the four sites investigated. At one of the two locations where stabilized metal finishing and paint waste had been landfilled calcium, sodium and chloride were significantly higher under and down the groundwater gradient from the site. At the electroplating disposal site sulfate and boron appeared at higher levels in groundwater downgradient from the waste disposal area. At the site where stabilized refinery wastes were landfilled increased levels of sulfite, nitrite, cyanide, phenols and arsenic were observed in water samples taken under and down the groundwater gradient from the site. Toxic metal contamination in groundwater was not detected at levels that would present a serious pollution problem.

Nitric acid digests of soils collected directly beneath the stabilized industrial wastes were compared to samples of soils from similar elevations outside the sites. Small increases in manganese, sodium, selenium and mercury were found at some sites, but most major toxic metals showed no consistent increase traceable to the wastes. Even the most highly "contaminated" soils were within the range of composition observed for natural eastern U. S. soils.

Distilled water extracts of soils collected beneath the stabilized wastes and at comparable elevations outside the site showed appreciable contrasts in chemical composition. Some of the toxic metals were present in consistently larger amounts in extracts from soils under the wastes. Chromium, lead and selenium were found in some extracts at levels above that acceptable for public drinking water supplies.

No major contamination of groundwater or soil could be detected under the stabilized wastes; but the sub-waste soils do contain larger quantities of leachable toxic metals than do background soil samples. This suggests that some toxic materials are escaping from the waste and are held in the soil in a readily leachable state.

SECTION 3

RECOMMENDATIONS

Collection of additional soil samples from beneath the disposal sites may reveal continued or increased contaminant release rates. Successive years of leaching and physical weathering may contribute significant amounts of contaminants to the soil and groundwater systems. Sampling soils periodically over several years can provide data to the established data base and serve as a case study of one type of stabilized sludges.

Disposal sites wherein untreated sludges are deposited should similarly be studied to ascertain the significance of stabilization. Disposal could be simulated using test cells with untreated sludge and others with stabilized sludges. The test cells would require limited space and if shallow in depth a relatively simple groundwater and subsoil monitoring system could be employed.

Data should be obtained from similar studies of other types of chemically stabilized and disposed sludges. Such a compilation will provide an assessment of the success of stabilization processes.

SECTION 4

MATERIALS AND METHODS

SITE SELECTION

Four industrial waste disposal areas from different geographic locations in the central United States were studied. All sites were in areas where rainfall and infiltration rates were sufficient to produce significant amounts of leachate. Anonominity was a condition for gaining permission to make sample borings at each site and therefore the sites are designated only by letter.

Three principal factors effecting the character and the amount of the contaminants leaching from an industrial waste disposal area are the waste type, amount of material disposed and the length of time the material has been buried. Secondary factors include the amount of rainfall and infiltration at the site, the thickness and surface area of the solidified waste and the character of the geologic materials under the disposal site. An attempt was made to carefully characterize each site. A summary of the important climatic, engineering and geologic characteristics of each site is given in Table 1. Figures 1-4 show the plan of each site and the location of test borings. Arrows in these figures indicate the most probable direction of groundwater movement deduced from water table maps and chemical data.

The same chemical stabilization/solidification system was employed at each of the four sites discussed in this report. The waste treatment system used involved mixing the wet sludge with cement, soluble silicates and other proprietary additives to produce a solid waste with soil-like properties. The exact proportion of waste and solidification agents used at these sites is not known.

Site W received approximately 20,000 cubic meters of treated paint and oil waste/residue in 1973-1974. This 1.5 hectare diked area had iron hydroxides, calcium, sulfates, silica, and lime putty among the chemical constituents. Prior to utilization as a disposal site for chemically fixed waste a portion of the area served as a waste burning pit. At the time of sampling, waste lagoons existed immediately west of the site. A surface water catchment basin was northeast of the site; each of these features contained liquid. The disposal area was not sheltered and the surface material was dry and loose. The moisture content increased with depth and a plastic consistency material was encountered at depths of less than one-half meter.

Site X was an 0.1 hectare, diked area consisting of approximately 1000 cubic meters of chemically fixed electroplating waste. The waste was

TABLE 1. SUMMARY OF CHARACTERISTICS OF THE FOUR SITES SELECTED

Characteristic	Site W	Site X	Site Y	Site Z
Geographic area within the U. S.	Central	North Central	North Central	South Central
General geologic setting	Glacial Drift	Glacial Outwash	Pleistocene - Lake Terrace	Deltaic - Fluvial Deposits
Mean annual rainfall	102 cm	93 cm	88 cm	117 cm
Mean annual air temperature	12°C	11°C	10°C	21°C
Nature of waste	Paint, putty	Electroplating	Paint, putty	Refinery sludge
Major pollutants detected in sludge analyses	B, Cr, Fe, Pb, Mn, Ni, Zn	Cd, Cr, Cu, Mn, Na, Zn	Cr, Fe, Pb, Mn, Zn	Pb, Mn, and phenol
Liner used below fill	None	None	None	None
Thickness of waste	1.22-3.05m (avg. 2.14m)	0.91-1.22m (avg. 1.07m)	Thin*	1.83-3.20m (avg. 3.79m)
Nature of material in unsaturated zone	Sandy clay	Sandy clay	Clayey sand	Clay
Thickness of unsaturated zone	3.05-8.60m (avg. 5.60m)	2.16-2.93m (avg. 2.41m)	1.46-11.80m (avg. 8.79m)	1.04-6.63m (avg. 3.79m)
Average hydraulic conductivity below waste	1.1×10^{-7} cm/sec	3.45×10^{-7} cm/sec	2.63×10^{-4} cm/sec	4.2×10^{-7} cm/sec
Character of covering material	None	None	None	Clay
Average thickness of cover	0.0	0.0	0.0	0.5m
Dates of emplacement of fixed sludge	1974	1973	1974*	1974
Type of operation	Diked fill	Diked fill	Fill	Diked fill and cover

* Fixed waste was placed on the ground in April and May 1974; but, the major portion of the fixed material was removed to a landfill in Jaunary 1975 when the area was regraded.

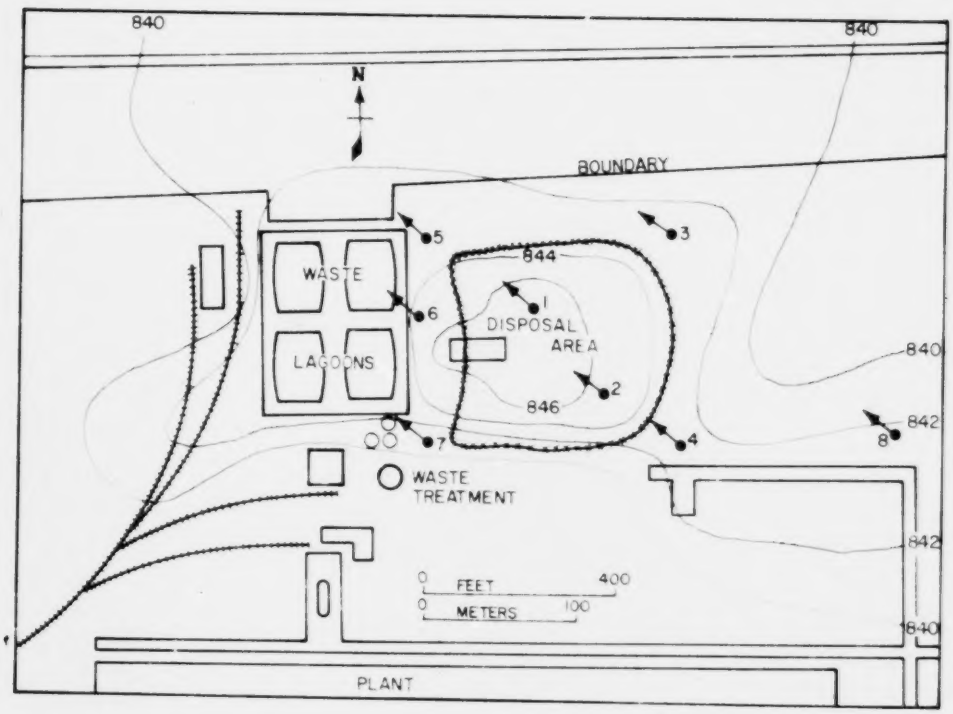

Figure 1. Location of borings at Site W. Arrows indicate most probable direction of groundwater movement.

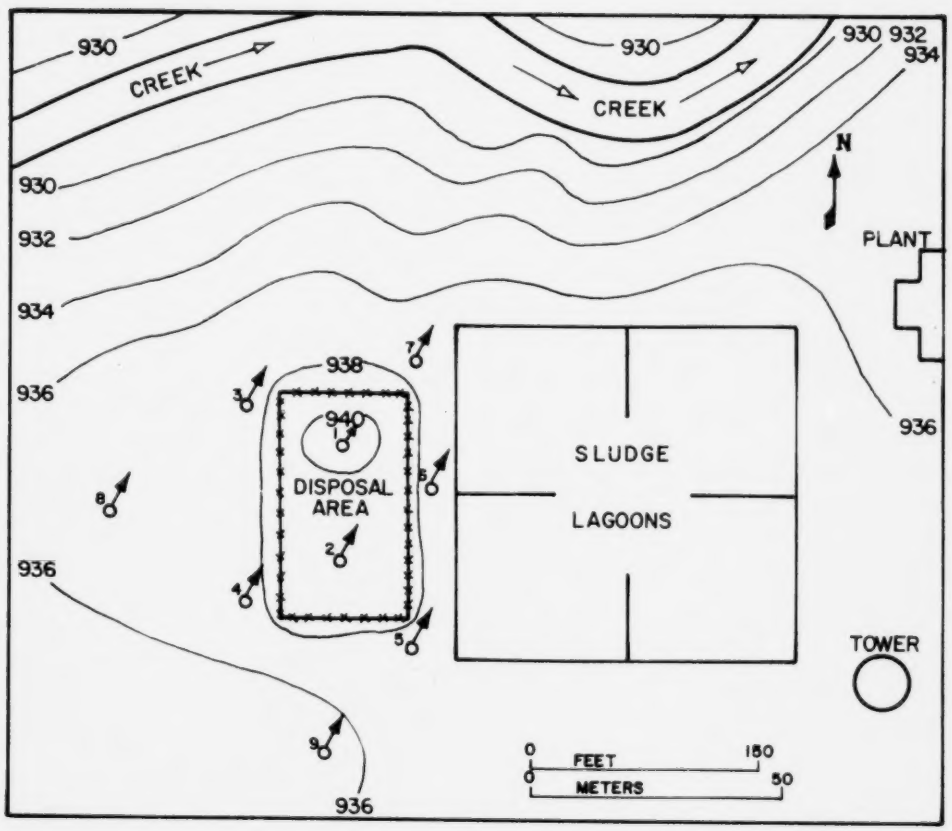

Figure 2. Location of borings at Site X. Arrows indicate most probable direction of groundwater movement.

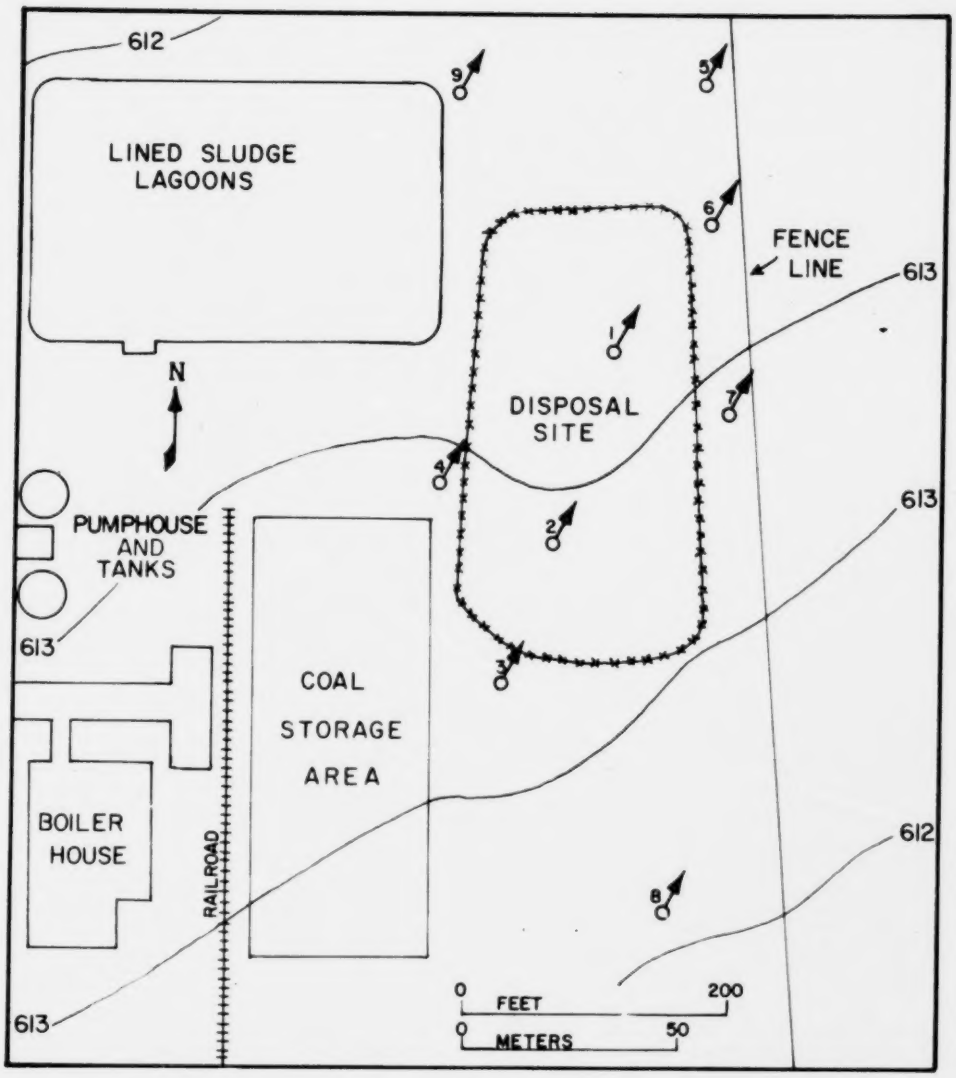

Figure 3. Location of borings at Site Y. Arrows indicate most probable direction of groundwater movement.

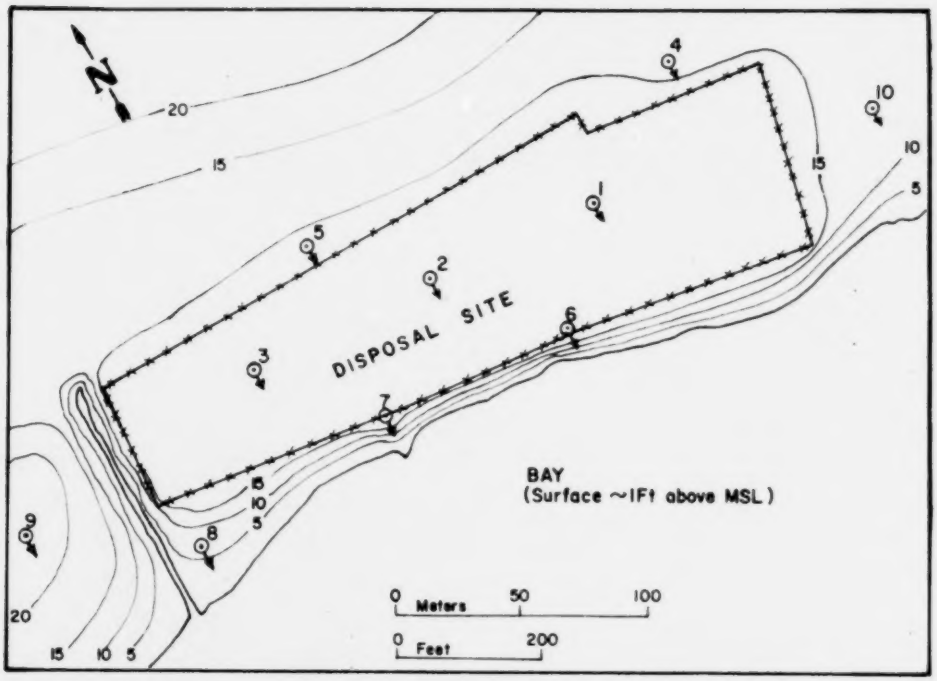

Figure 4. Location of borings at Site Z. Arrows indicate most probable direction of groundwater movement.

processed and deposited on the site in 1973 and no alteration of the area has occurred since deposition. The waste material was reported to contain oxides, salts, and hydroxides of zinc, cadmium, chromium, nickel, and tin. The waste was not covered and the surface material was dry and loose. This condition rapidly graded into a wet, plastic material ranging in depth from 25 to 50 centimeters.

The areal extent of Site Y was approximately 0.6 hectare. The chemically treated waste was deposited on site in 1974. Approximately eight months later, the material was transferred to a local landfill and the disposal site leveled. Areas within the site probably contained residue of the waste mixed with the soil, but none were observed at the time of sampling. The waste contained paint pigments, oil, iron, zinc, phosphate, and chromium. Sludge lagoons were located to the immediately northwest and a coal storage area was southwest of the sampled site. The site surface was sparsely vegetated and had some concrete rubble.

Site Z was a 1.4 hectare excavated and diked area containing approximately 15,000 cubic meters of treated refinery waste. The sludge contained 8-15 percent organics, 16-28 percent sediment, and 60-77 percent water. Chemical analyses confirmed the presence of chromium, iron, zinc, cadmium, copper, lead, nickel, and phenol. A drainage/waste impounding basin was northeast of the site and a bay inlet was to the south. The treated material was covered with 0.5 to 1.5 meters of top soil and clay and graded level. This cover was intermixed with the waste during the covering and leveling process and a precise interface horizon is not present. The surface cover was dry but graded into a wet, plastic material at depths of less than 1 meter.

Table 2 lists the concentrations of major potential chemical contaminants in the stabilized sludge at each site. Site W had relatively high levels of chromium, manganese, nickel, and zinc. Site X contained an electroplating waste notably high in cadmium, chromium, and copper. The waste at Site Y contained relatively low concentrations of toxic metals; only manganese was present in very large amounts. Site Z had high concentrations of a wide range of potential pollutants including chromium, lead, zinc and mercury. The waste at Site Z also contained a significant amount of phenol but the concentration was not quantified.

SAMPLING PROCEDURES

An initial sampling plan for all sites was established using the hypothetical model as shown in Figure 5. Some flexibility was necessary so that modifications could be made for any specific requirements at each disposal facility. The sampling plan included seven to ten borings to be made at each site. Where possible, two borings were to be drilled through the industrial waste and five to eight borings were to be drilled outside the disposal area. This sampling pattern allowed comparison between typical, uneffected groundwater and soil, and groundwater and soil which was in direct contact with the leachate migrating from each site.

TABLE 2. CONCENTRATIONS OF MAJOR CHEMICAL CONTAMINANTS IN THE FIXED SLUDGE AT EACH SITE*

Constituent	Site W (mg/kg)**	Site X (mg/kg)	Site Y (mg/kg)	Site Z (mg/kg)
B	43	35	10	6.4
Cd	4.5	105	0.1	1.8
Cr	230	1600	30	960
Cu	28	1650	18	130
Fe	47,000	4000	23,500	16,800
Pb	40	20	40	3,300
Mn	850	110	572	275
Ni	75	50	30	25
Se	1	1.3	0.62	0.83
Na	350	1281	2,000	1340
Zn	1,300	450	200	520
Hg	0.05	0.20	0.02	6.2
Phenol	--	--	--	Present

* Data obtained from analyses of sludge samples.
** On a dry wt basis.

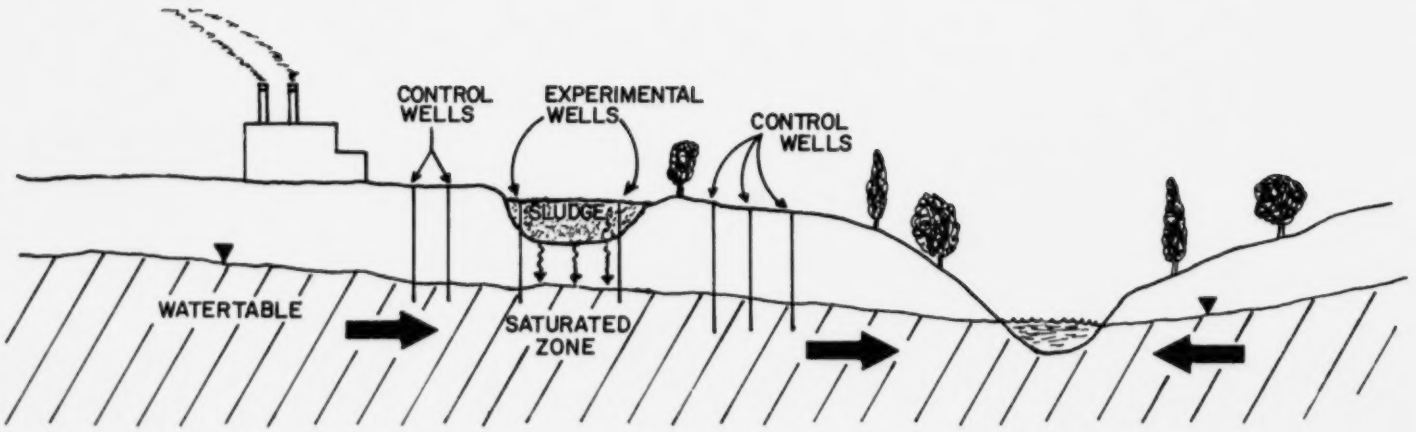

Figure 5. Hypothetical model of leachate and groundwater movement near industrial waste disposal site. Heavy arrows indicate groundwater movement.

All soil sampling was done with a truck-mounted, rotary drill using 16.8 cm OD, hollow-stem auger. The auger, with a central plug in place, was drilled to the desired depth. The central plug was then removed and a Hvorslev fixed-piston sampler (Figure 6) was pressed into the soil directly below the end of the auger using the hydraulic cylinders on the drill rig. In this way an undisturbed soil sample was obtained by extruding the soil core. A split-spoon sampler (Figure 7) was used in cases where objects were encountered in the subsurface that could not be penetrated by the Hvorslev sampler. When used, the split-spoon sampler was driven into the soil using a drop hammer and a sample was obtained by disassembling the split sampling barrel. Drilling logs for all borings are presented in the Appendix.

The down-hole samples were collected so as to maximize the probability of obtaining samples at two critical points in the boring. Since the strongest effects of leachate on the soil should occur directly below the wastes, a sample was always taken at the industrial waste-soil interface. Sampling below the interface was continued at closely spaced intervals. The top of the saturated zone (water table) was extrapolated from the water table measurements recorded in nearby wells. A series of closely spaced samples was taken in this interval. The borings were allowed to remain open for one to three days following the drilling to determine water table elevations. Depth to groundwater was determined using a battery operated water level indicator. Groundwater samples were obtained from the temporary wells by lowering a bailer into the hollow-stem auger. After a groundwater sample was obtained, the auger was removed and the holes were backfilled with grout and/or bentonite to a level above the water table. The backfilling was then completed with well cuttings. This was done to assure that the well would not act as a conduit for the flow of surface or contaminated water to the water table. Minor variations in the original sampling plan were necessary to collect the industrial waste samples. Auger wrap (material removed from the outside of the auger bit) was collected for chemical analysis. These auger wrap samples were collected only from the horizon containing the industrial waste. The physical properties of the soil samples were disturbed, but this was of no consequence to chemical analysis.

A descriptive identification code was assigned to each sample. The soil samples for chemical analysis were numbered consecutively down the bore hole - for example, "3C5" represents a sample from boring 3, chemical testing split (C), fifth sample down from the surface. Similar samples for physical testing were numbered "3P5". Only a single water sample was taken from each boring and therefore the sample number is that of the boring. The elevation above mean sea level, depth below the sludge/soil interface (negative numbers being samples from the treated sludge or cover material), and the height of the sample above or below the water table was noted for each sample collected.

SAMPLE HANDLING AND PREPARATION TECHNIQUES

Two sets of soil samples were collected in the well boring program; samples for physical testing and samples for chemical analysis. Groundwater samples were also taken from each boring for chemical analysis. The set of samples obtained for physical testing was used to determine soil class under

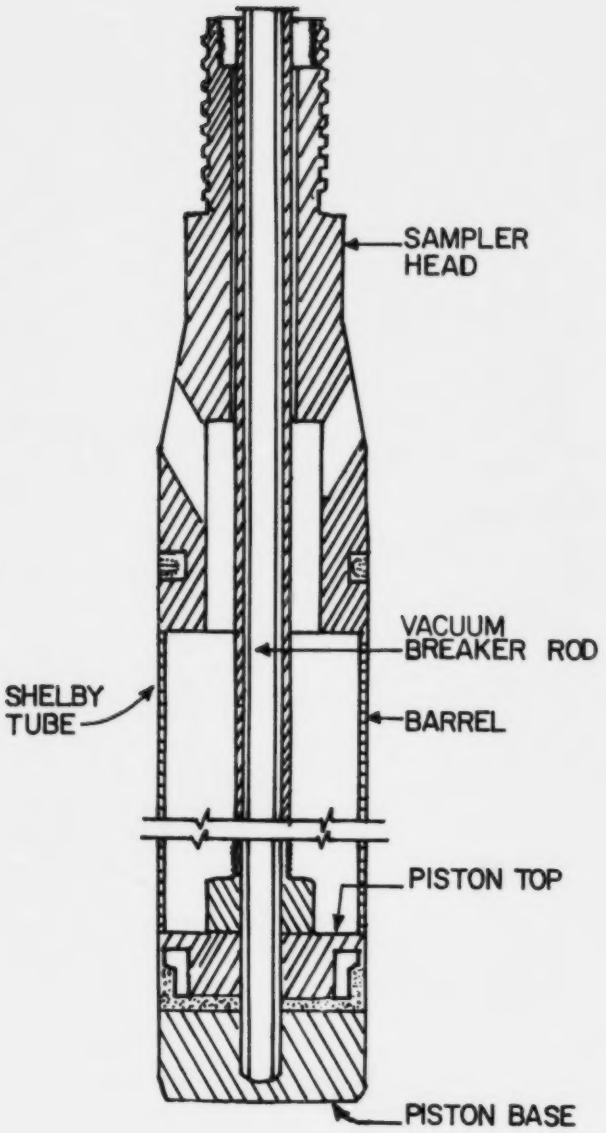

Figure 6. Diagram of Hvorslev Sampler

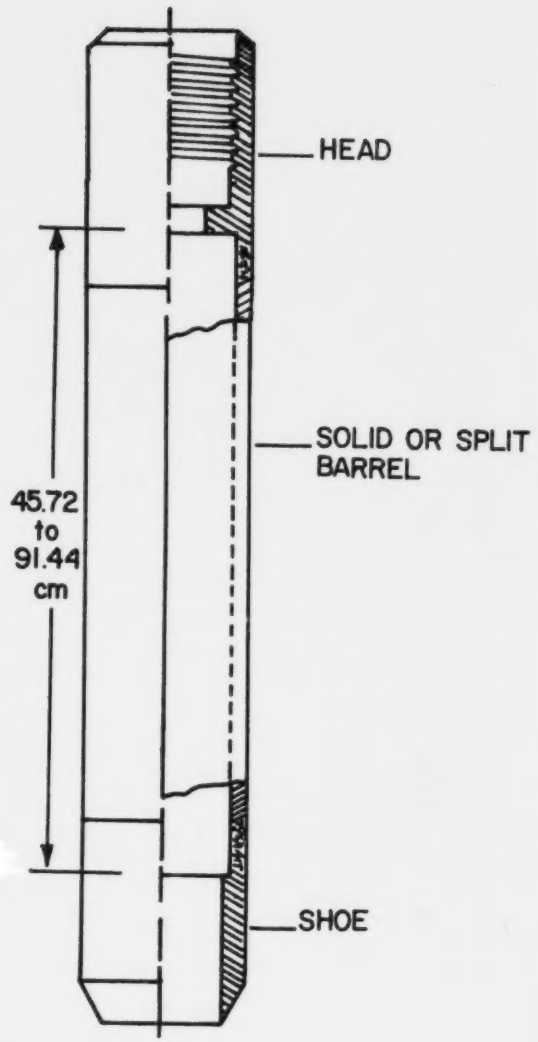

Figure 7. Diagram of split spoon sampler.

the unified soil classification system (9), dry density, grain-size distribution, water content and permeability. This sample set was collected as previously described with a Hvorslev, fixed-piston sampler and then carefully packaged and sealed in the Shelby tubes to retain the original moisture content and sample texture. Split-spoon samples were carefully removed and transferred to jars for transport back to WES.

All of the groundwater samples were collected from the borings by bailing the water from the center of the hollow-stem auger using a bailer made from small diameter tubing. The groundwater was transferred to polyethylene bottles which were labelled and packed in an insulated chest containing crushed ice. The samples were stored under refrigeration and kept tightly sealed until they were prepared for chemical analysis. The preparation consisted of centrifuging each sample at 2200 rpm for 30 minutes. The resulting supernatant was membrane-filtered through a 0.45 nm filter and split into five subsamples which were preserved for chemical analysis. The techniques used in all chemical analyses are given in Table 3.

Samples of soil for chemical analysis were collected simultaneously with the samples for physical testing, but, no attempt was made to maintain the physical integrity of the sample. Each sample was removed from the sampler or collected from the auger, placed in a wide-mouthed polyethylene bottle, and packed in an ice-filled chest. These soil samples were refrigerated during all subsequent transportation and/or storage. Two extracts were made from each soil sample: one with distilled water and one with 8N nitric acid. The materials that could be easily extracted with distilled water were considered transient and would readily be leached from the soil by dissolution in rainwater. Those obtained from the nitric acid digest contain the transient materials and also all the materials that could be solubilized by a strong, oxidizing acid. Those elements present as carbonates or sulfides, absorbed to clay minerals, to iron oxide or to insoluble organic materials would be freed (10); while elements in non-clay silicate lattices would be solubilized only to a minor degree (11).

For distilled water extracts, the contents of each sample bottle was mixed to assure a homogeneous sample. A 200-gram subsample of moist soil was weighed out into a 1000-ml polycarbonate centrifuge bottle and six hundred ml of distilled-deionized water was added to each. The centrifuge bottles were shaken on a rotary shaker for one hour, and then centrifuged at 2200 rpm for 30 minutes. The supernatant was filtered through a 0.45 nm membrane filter. The filtrate was split into five subsamples for chemical analysis.

A second soil subsample consisting of 50 grams of moist well-mixed soil was taken from each sample bottle for nitric acid digestion. In each digestion, the soil was weighed into a 250 ml fluorcarbon beaker and 60 ml of 8N reagent-grade nitric acid was added. The soil-acid suspension was heated to 95 deg C for 45 minutes and stirred every 15 minutes. After cooling to room temperature, the suspension was filtered through a 0.45 nm membrane filter. The digested soil was washed in the filter three times with 20-ml portions of 8N nitric acid. The filtrate was quantitatively transferred to a 250-ml volumetric flask and brought up to volume with 8N nitric acid and then stored

TABLE 3. TECHNIQUES USED IN THE ANALYSIS OF GROUNDWATER SAMPLES DISTILLED WATER EXTRACTS AND NITRIC ACID DIGESTS

Chemical species	Procedures and/or instrumentation*	Lowest reporting concentration (ppm)
SO_4	Standard Turbidimetric Method† in Combination with a Varian Model 635 Spectrophotometer	8
SO_3	Standard Potassium Iodide-Iodate Titration Method†	1
Cl	Standard Mercuric Nitrate Titration Method†	5
NO_3-N	Technicon II Auto-Analyzer, Industrial Method No. 100-70±	0.01
NO_2-N	Same as above	0.01
CN	Technicon II Auto-Analyzer, Industrial Method No. 315-75W±	0.01
TOC	Determined with Envirotech Model No. DC 50 TOC Analyzer	1
Phenol	Technicon II Auto-Analyzer, Industrial Method No. 127-71W	<0.01
Ca	Determined with a Spectrametrics Argon Plasma Emission Spectrophotometer Model II	0.03
Fe	Determined with Perkin-Elmer Heated Graphite Atomizer Atomic Absorption Unit	0.003
K	Determined with a Spectrametrics Argon Plasma Emission Spectrophotometer Model II	0.05
Mg	Same as above	0.03
Mn	Determined with Perkin-Elmer Heated Graphite Atomizer Atomic Absorption Unit	0.001
Na	Determined with Spectrametrics Argon Plasma Emission Spectrophotometer Model II	0.03
As	Determined with a Gaseous Hydride System, Perkin-Elmer Atomic Absorption Unit	0.003
B	Determined with a spectrametrics Argon Plasma Emission Spectrophotometer Model II	0.02
Be	Determined with a Perkin-Elmer Heated Graphite Atomizer Atomic Absorption Unit	0.005
Cd	Same as above	0.0003
Cr	Same as above	0.003
Cu	Same as above	0.003
Hg	Determined with a Nisseisangyo Zeeman Shift Atomic Absorption Spectrophotometer	0.0002
Ni	Determined with a Perkin-Elmer Heated Graphite Atomizer Atomic Absorption Unit	0.005
Pb	Same as above	0.002
Se	Same as above	0.005
Zn	Same as above	0.014

* Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

† Standard Methods for the Examination of Water and Wastewater, American Public Health Association, New York, 13th Edition, 1971.

± Technicon Industrial Systems, Tarrytown, New York.

in a polyethylene bottle. No preservation procedure was necessary.

A third subsample was taken from each sample bottle to determine the moisture content of the soil. These moisture contents were used to correct subsequent chemical analyses so that the results of soil extracts and acid digests could be expressed in milligrams per kilogram dry weight of soil.

PHYSICAL TESTING METHODS

The physical tests run on undisturbed samples included water content, dry density, permeability, and grain-size analysis. Data gathered from these tests and visual examination of the samples were used to classify the materials into standard soil engineering categories. All testing was done using standard soil engineering methods (7).

To determine water content, a sample taken from the sealed coring tube was weighed into a tared sample dish, dried at 110°C and weighed periodically until a constant weight was obtained.

Sample dry density (or dry unit weight) is the weight of oven-dried soil per unit volume of soil. This measurement was made using two different techniques depending on the sample: by trimming the soil sample into a precisely measured regular shape and drying and weighing the trimmed sample; or, by sealing the surface of a soil specimen with wax and measuring its volume by water displacement, then removing the sealing material and drying and weighing the specimen. The water displacement procedure was used with samples containing gravel or other coarse material that prevented the sample from being trimmed accurately.

Grain-size analysis was performed by sieving the dried, disaggregated soil through a standard sieve series. Standard hydrometer specific gravity measurements were run on a suspension prepared from the fraction passing the 200-mesh sieve.

Permeability measurements were made using a constant-head test system with coarse-grained soils, and a falling-head test system with fine sands or clays. In all cases, standard procedures and equipment were employed.

The major characteristics (especially grain-size analysis and characteristics of the fine fraction) of the samples were used to classify the soils. The classification system is summarized in Table 4. These classification categories and symbols are used to summarize soil characteristics in the Appendix.

TABLE 4. DESCRIPTIONS OF USCS SOIL GROUPS

Group symbol	Typical group description
GW	Well-graded (poorly sorted) gravels, gravel-sand mixtures, little or no fines
GP	Poorly graded (well-sorted) gravels, or gravel-sand mixtures, little or no fines
GM	Silty gravels, gravel-sand-silt mixtures
GC	Clayey gravels, gravel-sand-clay mixtures
SW	Well-graded (poorly sorted) sands, gravelly sands, little or no fines
SP	Poorly graded (well-sorted) sands, gravelly sands, little or no fines
SM	Silty sands, sand-silt mixtures
SC	Clayey sands, sand-clay mixtures
ML	Inorganic silts, very fine sands, clayey silts, low plasticity
CL	Inorganic clays, low to medium plasticity, lean clays
OL	Organic silts and organic silty clays of low plasticity
MH	Inorganic silts, micaceous or diatomaceous fine, sandy, or silty soils, elastic silts
CH	Inorganic clays of high plasticity, fat clays
OH	Organic clays of medium to high plasticity, organic silts
Pt	Peat and other highly organic soils

SECTION 5

RESULTS AND DISCUSSION

PHYSICAL TESTING

The soil parameters measured in the physical testing program are those expected to be most affected by the infiltration of leachate from overlying waste. The leachate suspension is filtered by the uppermost layer of soil below the waste. Filtration of the leachate should cause the soil to show:

a. an increase in density due to the addition of fine material in intergranular spaces,

b. a decrease in permeability due to accumulation of fine-grained particles in pore spaces,

c. an increase in the percentage of fine silt and clay size material (less than 200-mesh grain size),

d. an increase in water content due to the adsorption of water in the fines.

A complete tabulation of data obtained from the physical testing program is given in Tables 5-8. The goal of the physical testing was to see if soil characteristics had been altered in the soils beneath the industrial disposal operation. A summary contrasting the physical characteristics found in the samples from directly below the waste and at comparable elevations outside the landfill is given in Table 9. In most cases the contrast between samples at different locations at a disposal facility was found to be very slight. A randomization test (12) was applied to the data and in only two cases were the test results found to be so extreme as to be statistically significant (93% confidence level). The water content of sediments beneath the waste at site W is significantly higher than those outside the disposal area and the percent fines (<200 mesh) in samples under the landfill site X is significantly lower than corresponding samples outside the disposal area. No consistent pattern of changes in soil character can be seen. The expected effects of leachate filtration at the waste-soil interface were not generally detectable in the samples obtained in this study.

TABLE 5. PHYSICAL TESTING DATA FOR SAMPLES FROM SITE W

Boring no.	Sample no.	Depth (m)	Dry density (g/cc)	Water content (%)	Permeability or hydraulic cond. (cm/sec)	Classification
1	P1	3.23 - 3.76	1.92	14.8	1.8×10^{-7}	Sandy clay (CL) with gravel, dark gray
1	P2	4.15 - 4.72	2.00	13.1	4.4×10^{-8}	Sandy clay (CL) with gravel, dark gray
1	P3	5.36 - 5.76	2.03	11.6	8.9×10^{-7}	Sandy clay (CL) with gravel, dark gray
2	P1	1.40 - 1.62	1.73	16.0	2.2×10^{-6}	Sandy clay (CL), dark gray
2	P3	3.54 - 4.05	1.99	11.4	1.1×10^{-6}	Sandy clay (CL) with trace of gravel, dark gray
3	P4	3.23 - 3.60	1.99	12.2	3.2×10^{-6}	Sandy clay (CL) with trace of gravel, dark gray
3	P6	7.71 - 7.82	--	8.9	--	Sandy clay (CL) with trace of gravel, dark gray
4	P1	0.21 - 0.43	1.75	12.8	8.8×10^{-6}	Sandy silt (ML), brown
4	P3	2.38 -2.87	1.91	12.9	1.8×10^{-6}	Sandy clay (CL), light brown
4	P5	4.79 - 5.18	2.09	10.6	6.3×10^{-7}	Sandy, silty clay (CL-ML), dark gray
4	P6	6.16 - 6.28	--	10.5	--	Silty sand (SM), gray
5	P6	6.40 - 6.75	2.13	9.1	1.1×10^{-6}	Sandy clay (CL) with trace of gravel, dark gray
6	P3	3.26 - 3.72	1.92	13.9	5.1×10^{-7}	Sandy clay (CL) with trace of gravel, dark brown
7	P4	3.26 - 3.81	2.13	9.8	3.4×10^{-6}	Gravelly, silty sand (SM), brown
7	P5	4.72 - 4.92	2.10	8.1	3.3×10^{-6}	Clayey, sandy silt (CL-ML), gray
8	P6	6.31 - 6.52	2.05	10.1	4.0×10^{-7}	Clayey, sandy silt (CL-ML), gray

Note: -- indicates no data available.

TABLE 6. PHYSICAL TESTING DATA FOR SAMPLES FROM SITE X

Boring no.	Sample no.	Depth (m)	Dry density (g/cc)	Water content (%)	Permeability or hydraulic cond. (cm/sec)	Classification
1	P1	1.16 - 1.49	1.70	20.5	3.0×10^{-8}	Sandy clay (CL), brown
2	P1	1.43 - 1.77	1.56	21.7	4.5×10^{-7}	Clayey sand (SC) with gravel, dark gray
3	P1	0.24 - 0.64	1.78	18.3	7.4×10^{-8}	Sandy clay (CL), brown
3	P2	1.13 - 1.23	1.64	20.8	--	Sandy clay (CH), brown
4	P1	0.21 - 0.46	1.71	18.2	2.1×10^{-7}	--
5	P1	0.24 - 0.67	1.59	24.8	1.1×10^{-8}	Sandy clay (CH)
6	P1	0.27 - 0.46	1.88	14.5	1.4×10^{-7}	Silty clay (CL-ML), brown
7	P1	0.21 - 0.58	1.81	17.4	2.2×10^{-6}	Sandy clay (CL), brown
8	P1	0.24 - 0.52	1.62	21.2	1.3×10^{-8}	Sandy clay (CL) with gravel, brown
9	P1	0.24 - 0.55	1.69	20.2	2.0×10^{-8}	Sandy clay (CL) with gravel, brown

Note: -- indicates no data available.

TABLE 7. PHYSICAL TESTING DATA FOR SAMPLES FROM SITE Y

Boring no.	Sample no.	Depth (m)	Dry density (g/cc)	Water content (%)	Permeability or hydraulic cond. (cm/sec)	Classification
1	P1	0.27 - 0.64	1.73	18.6	8.3×10^{-7}	Clayey sand (SC), brown
1	P2	1.13 - 1.68	1.86	16.4	2.7×10^{-8}	Sandy clay (CL), gray
1	P3	1.89 - 2.26	2.00	12.5	7.9×10^{-9}	Sandy clay (CL) with gravel, brown
2	P1	0.21 - 0.76	1.73	17.4	1.3×10^{-6}	Sandy clay (CL), light brown
2	P2	1.16 - 1.62	1.93	14.4	3.1×10^{-8}	Sandy clay (CL), brown
2	P3	1.86 - 2.07	1.91	14.2	1.4×10^{-7}	Sandy clay (CL), dark brown
2	P4	7.86 - 8.08	1.61	10.7	3.9×10^{-4}	Silty sand (SM), dark brown
3	P3	1.92 - 2.44	1.75	19.5	4.4×10^{-8}	Lean clay (CL), with sand, brown
4	P1	0.21 - 0.64	1.66	22.8	6.1×10^{-9}	Lean clay (CL) with sand, light brown
4	P4	3.26 - 3.54	1.95	14.2	5.8×10^{-9}	Sandy clay (CL), gray
4	P6	7.89 - 8.11	1.58	16.0	$>1 \times 10^{-3}$	Silty sand (SM), gray
5	P2	1.13 - 1.68	1.73	17.4	5.1×10^{-7}	Silty sand (SM), brown
5	P4	3.29 - 3.72	1.58	--	$>1 \times 10^{-3}$	Silty sand (SM), dark brown
5	P7	10.03 - 10.49	1.51	23.0	3.9×10^{-4}	Clayey sand (SC) with gravel, brown
6	P6	7.89 - 8.38	1.54	15.8	1.6×10^{-3}	Silty sand (SM) with gravel, dark brown
7	P2	1.13 - 1.68	1.57	22.1	3.4 × 10-6	Clayey sand (SC), dark brown
7	P5	10.00 - 10.27	1.71	20.3	2.0×10^{-4}	Silty sand (SM), dark gray
9	P2	1.16 - 1.68	1.82	17.3	1.6×10^{-6}	Sandy clay (CL), light brown
9	P4	3.26 - 3.48	1.98	13.4	1.9×10^{-8}	Sandy clay (CL), light brown

Note: -- indicates no data available.

TABLE 8. PHYSICAL TESTING DATA FOR SAMPLES FROM SITE Z

Boring no.	Sample no.	Depth (m)	Dry density (g/cc)	Water content (%)	Permeability or hydraulic cond. (cm/sec)	Classification
1	P1	3.41 - 3.96	1.37	36.3	1.9×10^{-8}	Plastic clay (CH), tan
1	P3	5.61 - 5.97	1.57	26.5	1.9×10^{-9}	Plastic clay (CH) with trace of sand, brown
1	P5	8.05 - 8.38	1.68	22.4	2.0×10^{-8}	Plastic clay (CH) with sand, tan
1	P6	9.57 - 9.94	1.65	22.7	1.1×10^{-5}	Silt (ML) with sand, tan
2	P2	4.39 - 4.72	1.49	30.5	2.2×10^{-7}	Plastic clay (CH) with sand, tan
2	P4	6.52 - 6.92	1.65	22.6	1.0×10^{-9}	Sandy clay (CH), tan
3	P1	3.47 - 3.81	1.43	32.8	5.2×10^{-9}	Plastic clay (CH) with trace of sand, light brown
3	P3	5.61 - 5.97	1.70	21.5	1.1×10^{-8}	Plastic clay (CH) with sand, light brown
3	P4	6.52 - 6.92	1.52	--	4.8×10^{-9}	Sandy clay (CH) with gravel, light brown
4	P2	3.63 - 3.99	1.45	32.0	1.5×10^{-8}	Plastic clay (CH) with trace of sand, light brown
4	P4	5.76 - 6.13	1.55	--	3.3×10^{-6}	Sandy clay (CH), light gray
4	P5	7.28 - 7.71	1.67	21.2	1.1×10^{-8}	Plastic clay (CH) with sand, light brown
5	P1	2.71 - 3.02	1.38	34.8	2.9×10^{-9}	Plastic clay (CH) with trace of sand, tan
5	P3	4.85 - 5.24	1.65	23.7	4.4×10^{-9}	Plastic clay (CH) with trace of sand, reddish brown

(continued)

Note: -- indicates no data available.

TABLE 8 (continued)

Boring no.	Sample no.	Depth (m)	Dry density (g/cc)	Water content (%)	Permeability or hydraulic cond. (cm/sec)	Classification
5	P5	7.28 - 7.71	1.67	22.2	1.1×10^{-6}	Lean clay (CL) with sand, tan
6	P1	3.32 - 3.63	1.43	31.4	--	Plastic clay (CH), tan
6	P2	4.24 - 4.57	1.57	25.6	--	Plastic clay (CH) with trace of sand, tan
6	P4	6.37 - 6.77	1.62	24.1	--	Plastic clay (CH), tan
6	P6	9.42 - 9.72	1.65	22.9	--	Sandy clay (CH), tan
7	P1	3.32 - 3.66	1.51	28.8	--	Plastic clay (CH) with trace of sand, tan
7	P3	5.46 - 5.88	1.75	19.7	--	Lean clay (CL) with sand, tan
7	P5	7.89 - 8.26	1.68	22.5	--	Plastic clay (CH) with trace of sand, tan
8	P1	0.15 - 0.45	1.11	42.6	--	Silty sand (SM) with trace of organic matter, dark gray
8	P3	2.41 - 2.80	1.60	25.4	--	Plastic clay (CH) with trace of sand, yellowish gray
8	P5	4.85 - 5.24	1.72	21.2	--	Lean clay (CL) with trace of sand
9	P3	7.86 - 8.17	1.37	34.8	5.2×10^{-9}	Sandy clay (CH), gray
9	P4	8.81 - 9.11	1.55	26.1	1.3×10^{-8}	Sandy clay (CH) with gravel, tan
9	P5	10.33 - 10.76	1.62	23.8	3.8×10^{-8}	Plastic clay (CH), tan
10	P2	3.02 - 3.38	1.49	29.1	--	Plastic clay (CH) with trace of sand
10	P4	5.15 - 5.51	1.53	28.6	--	Plastic clay (CH) with trace of sand, gray

TABLE 9. COMPARISON OF PHYSICAL PROPERTIES OF SOIL SAMPLES COLLECTED DIRECTLY BENEATH AND AT COMPARABLE DEPTHS OUTSIDE THE DISPOSAL AREAS

Site	Boring no.	Position with respect to disposal area	Depth below surface (m)	Dry density (g/cc)	Water content (%)	Hydraulic conductivity (cm/sec)	%Fines*	Classification
W	1	inside	3.23 - 3.76	1.92	14.8	1.8×10^{-7}	58	Sandy clay with gravel
W	2	inside	1.40 - 1.62	1.73	16.0	2.2×10^{-6}	74	Sandy clay
W	3	outside	3.23 - 3.60	1.99	12.2	3.2×10^{-6}	58	Sandy clay with gravel
W	4	outside	0.21 - 0.43	1.75	12.8	8.8×10^{-6}	74	Sandy silt
W	5	outside	6.40 - 6.75	2.13	9.1	1.1×10^{-7}	--	Sandy clay with gravel
W	6	outside	3.76 - 3.72	1.92	13.9	5.1×10^{-7}	60	Sandy clay with gravel
W	7	outside	3.26 - 3.81	2.13	9.8	3.4×10^{-6}	34	Gravelly, silty sand
W	8	outside	6.31 - 6.52	2.05	10.1	4.0×10^{-7}	52	Clayey, sandy silt
X	1	inside	1.16 - 1.49	1.70	20.5	3.0×10^{-8}	60	Sandy clay
X	2	inside	1.43 - 1.77	1.56	21.7	4.5×10^{-7}	46	Sandy clay
X	3	outside	0.24 - 0.64	1.78	18.3	7.4×10^{-8}	76	Sandy clay
X	4	outside	0.21 - 0.46	1.71	18.2	2.1×10^{-7}	--	-----
X	5	outside	0.24 - 0.67	1.59	24.8	1.1×10^{-8}	63	Sandy clay
X	6	outside	0.27 - 0.46	1.88	14.5	1.4×10^{-7}	82	Silty clay
X	7	outside	0.21 - 0.58	1.81	17.4	2.2×10^{-6}	67	Sandy clay
X	8	outside	0.24 - 0.52	1.62	21.2	1.3×10^{-8}	65	Sandy clay with gravel
X	9	outside	0.24 - 0.55	1.69	20.2	2.0×10^{-8}	61	Sandy clay with gravel
Y	1	inside	0.27 - 0.64	1.73	18.6	8.3×10^{-7}	--	Clayey sand
Y	2	inside	0.21 - 0.76	1.73	17.4	1.3×10^{-6}	84	Sandy clay
Y	3	outside	1.92 - 2.44	1.75	19.5	4.4×10^{-8}	88	Clean clay
Y	4	outside	0.21 - 0.64	1.66	22.8	6.1×10^{-9}	88	Sandy clay
Y	5	outside	1.13 - 1.68	1.73	17.4	5.1×10^{-7}	42	Silty sand
Y	7	outside	1.13 - 1.68	1.57	22.1	3.4×10^{-6}	44	Clayey sand
Y	9	outside	1.16 - 1.68	1.82	17.3	1.6×10^{-6}	87	Sandy clay
Z	2	inside	4.39 - 4.72	1.48	30.5	2.2×10^{-7}	95	Plastic clay with sand
Z	3	inside	3.48 - 3.81	1.43	32.8	5.2×10^{-9}	96	Plastic clay with trace sand
Z	4	outside	3.63 - 3.99	1.45	32.0	1.5×10^{-8}	96	Plastic clay with trace sand
Z	5	outside	2.71 - 3.02	1.38	34.8	2.9×10^{-9}	96	Plastic clay with trace sand
Z	6	outside	3.32 - 3.63	1.43	31.4	---	97	Plastic clay
Z	7	outside	3.32 - 3.72	1.51	28.8	---	94	Plastic clay
Z	8	outside	2.41 - 2.80	1.60	25.4	---	95	Plastic clay

* % Fines = percent <200 mesh.

CHEMICAL ANALYSES OF GROUNDWATER

Tables 10 through 13 summarize the results of the chemical analyses of groundwater samples obtained from borings at the four industrial waste sites. In examining the sites for possible groundwater contamination, wells drilled up the groundwater gradient from the disposal site were considered to be providing control or background water samples not contaminated by the disposal activities. Wells drilled through the solidified waste or down the groundwater gradient from the site are considered experimental wells where any possible contamination from the waste would be detected.

In the experimental borings through the disposal sites, the concentrations of major cations and anions (Ca, Na, SO_4 and Cl) were often high suggesting contamination from the overlying waste; yet, the toxic metal levels were remarkably low. A randomization test (12) was used to determine which constituents were present in consistently high concentrations in either experimental or control samples. The results are summarized in Table 14.

At Site W, only chloride, nitrite, calcium and sodium showed significant elevated concentrations in the experimental borings. Nitrite levels, however, were very close to the limit of detection for the analytical method used and the small variation observed does not suggest this is a major contaminant leaching from the waste. Concentrations of chloride, calcium and sodium were all well above the detection limits and the contrast between control and experimental samples was impressive.

At Site X, only sulfate, nitrate and boron showed significant differences between control and experimental samples. At this site, however, high nitrate levels were found in the control wells and not in the experimental wells. The control wells were drilled in a farmed area west and south of the disposal area and may have been contaminated by fertilizer leaching from this agricultural land. Only sulfate and boron levels increased under the fixed sludge disposal area.

At Site Y, the wells that were bored on the southwest side of the sludge disposal site were in close proximity to a coal storage area for the plant boiler house. Seepage from the coal pile probably accounts for the very high sulfate levels in the two upgradient wells. The plume of contaminated water continued under the sludge disposal area making it difficult to establish which pollutants were contributed by the fixed sludge. Only boron showed a statistically significant difference in concentration between the control and experimental wells. Boron was higher in the control wells than in the experimental wells suggesting it was coming from the coal storage area, not the sludge disposal site.

At Site Z, the sludge disposal area is between a tank farm and a small brackish bay. The combination of these circumstances results in high background levels of many constituents in the groundwater. The randomization test indicated the occurrence of significantly higher levels of sulfite, nitrite, cyanide, phenols and arsenic in the experimental wells. The concentrations of chromium observed also were significant statistically; however, the levels of chromium observed were very close to the limit of detection

TABLE 10. CHEMICAL COMPOSITION OF GROUNDWATER OBTAINED FROM BORINGS AT SITE W

Parameters	Experimental Borings				Control Borings			
	1	2	5	6	3	4	7	8
SO_4	600	1049	299	1542	142	400	342	182
SO_3	<1	<1	<1	<1	<1	<1	<1	<1
Cl	55	50	50	26	5	15	25	20
NO_3-N	0.55	0.18	0.08	0.77	1.17	0.08	0.38	0.08
NO_2-N	0.01	<0.01	0.02	0.01	<0.01	<0.01	0.01	<0.01
CN	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.05	<0.01
TOC	4	32	8	12	3	8	6	2
Ca	191.00	554.00	155.00	402.00	113.00	83.10	171.00	92.80
Fe	ND	0.141	0.150	0.219	0.094	ND	0.118	ND
Mg	69.10	88.30	80.70	165.00	50.00	40.40	94.30	43.40
Mn	0.121	0.049	0.344	0.719	0.049	0.152	0.196	0.050
Na	92.10	88.90	35.70	226.00	10.90	11.90	9.80	8.50
As	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
B	0.03	0.03	0.34	4.60	0.04	0.03	0.03	0.03
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Cr	<0.003	<0.003	<0.003	0.003	0.003	<0.003	<0.003	<0.003
Cu	ND	ND	0.004	<0.003	0.003	ND	<0.003	<0.003
Hg	<0.0002	ND	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Ni	0.016	0.027	0.009	0.160	0.025	<0.005	0.009	<0.005
Pb	0.002	0.002	<0.002	<0.002	<0.002	0.005	0.013	<0.002
Se	<0.005	<0.005	0.013	0.033	0.026	<0.005	0.006	0.009
Zn	<0.014	<0.014	0.015	0.042	0.020	<0.014	0.021	<0.014

Note: All values are in mg/ℓ.
ND = Not determined.

TABLE 11. CHEMICAL COMPOSITION OF GROUNDWATER OBTAINED FROM BORINGS AT SITE X

Parameters	Experimental Borings				Control Borings				
	1	2	6	7	3	4	5	8	9
SO_4	272	502	292	262	202	ND	117	117	<8
SO_3	<1	<1	<1	<1	<1	ND	<1	<1	<1
Cl	25	35	15	25	15	ND	35	15	5
NO_3-N	0.10	1.80	0.40	0.71	18.60	ND	1.00	18.60	14.30
NO_2-N	<0.01	0.05	<0.01	<0.01	<0.01	ND	0.14	<0.01	<0.01
CN	0.05	0.12	0.04	0.04	0.05	ND	0.02	0.05	0.01
TOC	5	13	13	8	5	ND	12	7	10
Ca	40.00	82.00	116.00	113.00	94.30	83.10	66.20	88.10	99.00
Fe	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mg	54.20	35.40	72.30	68.10	51.20	49.80	30.60	52.30	55.10
Mn	0.023	0.014	1.130	0.631	0.305	0.173	0.193	0.001	0.393
Na	85.00	119.00	71.10	44.40	73.30	71.90	38.20	45.50	15.60
As	<0.003	0.004	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
B	0.04	0.05	0.10	0.08	0.03	0.03	0.05	0.04	0.04
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Cr	<0.003	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.006
Cu	<0.003	0.005	0.003	<0.003	<0.003	ND	<0.003	<0.003	0.005
Hg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	ND	<0.0002	<0.0002	<0.0002
Ni	<0.005	<0.005	0.009	<0.005	0.009	<0.005	<0.005	<0.005	<0.005
Pb	<0.002	<0.002	<0.002	0.008	<0.002	0.005	<0.002	<0.002	0.002
Se	0.009	0.016	0.011	0.006	0.016	0.005	0.013	0.019	0.006
Zn	<0.014	<0.014	0.037	0.042	<0.014	0.03?	<0.014	<0.014	0.014

Note: All values are in mg/ℓ.
ND = Not determined.

TABLE 12. CHEMICAL COMPOSITION OF GROUNDWATER OBTAINED FROM BORINGS AT SITE Y

Parameters	Experimental Borings					Control Borings			
	1	2	5	6	7	3*	4*	8	9
SO_4	500	950	950	500	400	1100	800	200	500
SO_3	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cl	130	100	130	60	65	130	110	35	55
NO_3-N	0.04	0.24	0.01	1.60	0.20	0.05	0.13	0.19	0.16
NO_2-N	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	0.02	0.01	<0.01
CN	<0.01	ND	<0.01	ND	<0.01	ND	ND	<0.01	ND
TOC	32	ND	4	ND	8	ND	ND	4	2
Ca	131.00	355.00	338.00	266.00	234.00	346.00	328.00	151.00	252.00
Fe	ND	0.336	0.107	ND	ND	0.102	0.100	ND	ND
Mg	49.80	119.00	115.00	83.60	67.30	147.00	106.00	39.20	79.60
Mn	0.137	0.550	0.410	0.006	1.270	1.07	0.707	0.827	0.377
Na	272.00	48.90	77.00	28.50	38.40	77.00	47.80	33.00	27.40
As	<0.003	0.010	0.008	0.006	0.005	0.012	0.008	0.012	0.010
B	0.06	0.05	0.04	0.03	0.04	0.07	0.10	0.04	0.05
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	<0.0003	<0.0003	0.0006	<0.0003	0.0004	<0.0003	0.0003	0.0004	<0.0003
Cr	<0.003	0.004	<0.003	<0.003	<0.003	0.003	<0.003	<0.003	<0.003
Cu	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hg	<0.0002	ND	<0.0002	<0.0002	<0.0002	ND	ND	<0.0002	<0.0002
Ni	0.013	0.052	<0.005	<0.005	0.020	0.021	0.021	0.022	0.015
Pb	0.003	<0.002	0.003	<0.002	0.002	<0.002	0.002	0.002	0.003
Se	<0.005	0.005	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005
Zn	<0.014	0.023	<0.014	<0.014	<0.014	<0.014	0.040	<0.014	0.028

Note: All values are in mg/ℓ.
ND = Not determined.
* These two borings were made in an area suspected of being contaminated by runoff from a coal storage area.

TABLE 13. CHEMICAL COMPOSITION OF GROUNDWATER OBTAINED FROM BORINGS AT SITE Z

Parameters	Experimental Borings						Control Borings			
	1	2	3	6	7	8	4	5	9	10
SO_4	24	23	158	14	79	163	<8	20	50	24
SO_3	<1	3	25	3	<1	<1	<1	<1	<1	<1
Cl	585	1500	1360	390	1010	1780	960	995	660	1630
NO_3-N	0.251	0.08	<0.01	0.13	0.02	2.35	0.01	<0.01	<0.01	0.04
NO_2-N	0.04	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CN^-	0.02	<0.01	0.60	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
TOC	22	24	419	13	11	17	29	21	13	17
Phenol	0.06	<0.01	6.90	0.02	0.03	0.08	0.03	<0.01	0.01	0.03
Ca	206.00	349.00	241.00	161.00	362.00	354.00	226.00	277.00	175.00	294.00
Fe	0.566	11.300	ND	ND	ND	ND	ND	ND	ND	ND
K	2.80	2.00	2.70	1.20	1.80	1.50	3.00	2.30	1.00	1.10
Mg	37.50	71.70	72.70	17.60	62.40	90.50	53.50	62.40	38.00	82.90
Mn	1.230	0.622	0.103	0.542	1.050	0.049	0.030	0.155	0.408	0.201
Na	271.00	691.00	762.00	249.00	408.00	784.00	474.00	464.00	412.00	691.00
As	0.007	0.007	0.016	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
B	0.07	0.15	0.07	0.07	0.06	0.12	0.08	0.09	0.17	0.26
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	0.0028	0.1070	0.0056	0.0048	0.0080	0.0176	0.0078	0.0075	0.0016	0.0151
Cr	0.003	0.004	0.003	<0.003	0.003	0.003	0.003	0.003	0.005	0.005
Cu	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hg	0.0004	<0.0002	<0.0002	0.0002	<0.0002	0.0010	0.0002	<0.0002	0.0003	<0.0002
Ni	0.014	0.028	0.191	<0.005	0.006	<0.005	<0.005	<0.005	<0.005	0.006
Pb	0.004	0.002	0.003	0.002	0.003	0.003	0.002	0.002	0.003	0.003
Se	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zn	ND	ND	0.112	ND	ND	ND	ND	ND	ND	ND

Note: All values are in mg/ℓ.
ND = Not determined.

TABLE 14. RESULTS OF RANDOMIZATION TEST OF GROUNDWATER SAMPLES DIRECTLY UNDER THE DISPOSAL SITES AND OUTSIDE THE SITES

Site	W	X	Y	Z
SO_4	NS	S	NS	NS
SO_3	--	--	--	S
Cl	S	NS	NS	NS
NO_3-N	NS	S	NS	NS
NO_2-N	S	NS	NS	S
CN	NS	NS	ND	S
TOC	NS	NS	ND	NS
Phenol	ND	ND	ND	S
Ca	S	NS	NS	NS
Fe	ND	ND	ND	ND
Mg	NS	NS	NS	NS
Mn	NS	NS	NS	NS
Na	S	NS	NS	NS
As	--	--	NS	S
B	NS	S	S	NS
Be	--	--	--	--
Cd	--	--	NS	NS
Cr	--	--	NS	S
Cu	--	NS	ND	ND
Hg	--	--	--	NS
Ni	NS	--	NS	NS
Pb	NS	NS	NS	NS
Se	NS	NS	NS	--
Zn	NS	NS	NS	ND

-- = Too few samples above detection limit.
NS = Not significant at 94-96% level.
S = Significant at 94-96% level.
ND = Too many samples not determined.

for the analytical technique used and the chromium levels were higher in the control borings than in the experimental borings. The fixed sludge contained a great deal of oil and the groundwater samples from under the disposal area smelled strongly of oil and phenol. The decomposition of these oily materials may account for the production of sulfite and nitrite, as well as, the persistence of cyanide that may have been present in the refinery sludge. The phenols and arsenic are probably migrating directly from the fixed sludge.

Changes in groundwater quality attributable to sludge disposal could be observed in three of the four sites investigated. At one of the two sites where stabilized metal finishing and paint wastes had been disposed of the levels of chloride, calcium and sodium showed significant increases under and down the groundwater gradient from the disposal site. At the electroplating facility, sulfate and boron levels increased under and down the groundwater gradient from the disposal site. At the disposal site for stabilized refinery sludge, increased levels of sulfite, nitrite, cyanide, phenols, and arsenic were found in water samples taken under and down the groundwater gradient from the disposal sites.

With the exception of phenols at site Z, none of the toxic constituents predicted to be pollution problems on the basis of analysis of the waste material (Table 2) were found in significantly elevated concentrations in the groundwater. The absence of these pollutants may be attributable to binding of these constituents in the stabilization process, lack of time for transport of these materials to the groundwater, and/or attenuation effects occurring in the soils.

CHEMICAL ANALYSIS OF NITRIC ACID EXTRACTS

Chemical analyses of nitric acid extracts are summarized in Tables 15-22. At site W, the major materials disposed were sludges produced in an automobile assembly plant. As can be seen in samples 1C1, 1C2, 2C1, and 2C2 (Table 16), the sludges differ from surrounding soils in having elevated concentrations of all metals determined. The major potential contaminants are boron, chromium, iron, lead, manganese, nickel, and zinc; also, sodium and selenium. Elevated levels of most contaminants were only evident in the samples from the first meter below the sludge/soil interface. No soils samples recovered from borings more than 1 m below the sludge/soil interface had metals levels above that observed in the surrounding uncontaminated soils except in the case of selenium. Selenium levels were higher in deep (greater than 1 m) soils samples in both experimental borings at site W.

A randomization test was used to detect differences in metal contents between soils collected immediately below the sludge disposal site and those taken from similar elevations outside the disposal area. Significantly elevated levels were found for manganese, sodium, and selenium in samples from the sludge disposal area (Table 23).

The waste disposed at Site X was treated electroplating waste. The major potential pollutants contained in this sludge were cadmium, chromium, copper, sodium, and zinc; other constituents present in the sludge at levels in excess of that found in the surrounding soils were boron, mercury, nickel, lead, and selenium. Several metals (iron, potassium, and manganese) were much less prevalent in the treated sludge than in the local soils. No soils samples were taken below 1-m depth under the sludge/soil interface. Significantly elevated levels of sodium and mercury were found in the digest of the soil from less than 1 m under the treated sludge when compared to surrounding soils at similar elevations (Table 23).

Soluble sodium compounds are added to the wastes during the stabilization/solidification processing. The presence of sodium at elevated levels in the soil is consistent with the high level of sodium in the wastes (Table 2). The mercury levels in the soil digests were consistently high for soils collected directly below the waste; but some background (control) samples were as high as the lowest sample collected below the waste.

The treated automobile assembly plant waste (largely paint and putty) deposited at site Y had been in place for approximately nine months before the material was removed to a landfill and the area was regraded. Major potential pollutants from this treated sludge were chromium, iron, lead, manganese, sodium, and zinc. Only sodium and selenium were found at significantly elevated levels in soils samples taken near the surface from which the treated sludge had been removed (Table 23). However, high levels of chromium, lead, and zinc were found in samples from the upper level of one of the experimental holes (1C1, Table 20). The sodium levels in the soils samples taken approximately 1 m deeper in both experimental holes (samples 1C2 and 2C2) were still slightly above the range of sodium levels in the surrounding soils. Sodium levels for soils samples taken from greater depths below the sludge/soil interface were within the range of sodium levels in the surrounding soil.

TABLE 15. ANALYSES OF NITRIC ACID DIGESTS OF SOIL SAMPLES FROM CONTROL BORINGS AT SITE W

Boring and sample	3C1	3C2	3C3	3C4	3C5	3C6	4C6	5C1
Elevation (m)	256.84	255.93	254.71	253.81	251.20	249.37	250.75	256.68
Ht. above water table (m)	6.16	5.25	4.03	3.13	0.52	-1.31	-1.02	5.63
Conc. (mg/kg dry wt.)								
Fe	17024.76	16985.11	13627.81	12422.47	14003.01	15313.91	8674.08	14464.37
K	634.06	692.73	546.98	645.28	687.69	897.67	380.32	618.49
Mn	445.30	403.24	378.62	291.06	344.21	420.64	258.93	364.36
Na	110.71	100.59	111.59	120.52	111.70	124.55	100.51	141.87
B	10.23	9.68	10.34	10.75	10.00	10.15	6.39	12.80
Be	0.23	0.49	0.34	0.29	0.31	0.32	0.08	0.32
Cd	2.18	2.04	1.79	1.59	1.43	1.70	1.08	2.01
Cr	40.15	20.56	17.17	17.68	16.31	17.68	10.02	17.68
Cu	27.59	18.12	14.27	13.16	12.42	14.21	8.51	20.77
Hg	0.03	0.01	0.01	0.04	0.02	0.01	0.01	0.02
Ni	21.17	24.24	19.34	17.93	15.20	18.49	10.27	18.68
Pb	11.74	10.44	10.98	7.42	6.67	7.38	5.34	21.33
Se	0.25	0.24	0.25	0.23	0.23	0.23	0.23	0.23
Zn	126.64	57.32	53.42	50.16	43.68	90.41	35.59	82.43

continued

TABLE 15. (continued)

Boring and sample	5C6	6C1	6C5	7C1	7C2	7C3	7C4	7C5	8C6
Elevation (m)	250.60	257.07	252.68	255.97	255.21	253.99	253.07	251.55	250.55
Ht. above water table (m)	-0.45	2.33	-2.06	2.82	2.06	0.84	-0.07	-1.60	1.33
Conc. (mg/kg dry wt.)									
Fe	12693.60	18631.07	9209.18	13957.05	23965.56	13565.70	8430.77	9744.03	13705.00
K	584.46	667.09	432.44	377.54	608.69	575.11	373.00	263.86	621.41
Mn	393.56	329.14	299.06	358.99	522.73	390.73	235.49	199.62	301.32
Na	126.09	185.36	143.85	89.13	79.02	111.77	121.34	94.87	109.83
B	11.25	28.58	10.61	6.76	11.98	13.18	11.14	7.64	10.70
Be	0.23	0.77	0.27	0.36	0.73	0.29	0.19	0.06	0.22
Cd	1.40	3.00	1.18	1.50	2.55	1.73	1.20	1.10	1.36
Cr	14.54	23.82	11.99	12.17	19.67	14.86	12.81	26.04	14.22
Cu	12.01	120.67	9.47	8.21	21.71	13.66	45.21	10.48	43.37
Hg	0.01	0.07	0.01	0.02	0.02	0.01	0.01	0.01	0.01
Ni	15.80	23.98	12.75	9.28	30.61	19.06	18.29	8.21	14.97
Pb	6.82	22.20	14.03	6.73	10.42	8.60	8.99	3.96	6.57
Se	0.14	0.16	0.18	0.08	0.25	0.47	0.49	0.68	0.33
Zn	36.98	158.32	35.70	38.51	72.59	53.02	83.77	29.15	43.37

TABLE 16. ANALYSIS OF NITRIC ACID DIGESTS OF SOIL SAMPLES FROM EXPERIMENTAL BORINGS AT SITE W

Boring and sample	1C1	1C2	1C3	1C4	1C5	1C6	1C7
Elevation (m)			255.87	254.94	253.73	252.79	250.54
Depth below sludge/soil interface (m)			0.07	1.00	2.21	3.15	5.40
Ht. above water table (m)			2.49	1.56	0.35	-0.59	-2.84
Conc. (mg/kg dry wt.)							
Fe	67709.41	38777.90	30192.42	13621.28	11407.92	13340.41	14054.88
K	211.66	1080.86	768.45	468.35	558.44	580.90	721.00
Mn	1063.65	779.20	893.51	336.76	305.40	328.41	384.19
Na	361.76	601.98	317.91	107.29	111.32	113.14	114.08
B	50.10	30.27	9.40	8.99	9.74	10.80	10.12
Be	0.56	0.46	0.83	0.38	0.36	0.39	0.42
Cd	6.36	4.39	3.33	0.30	0.26	0.89	0.13
Cr	367.12	195.69	21.41	9.94	9.44	9.68	10.37
Cu	40.71	41.73	29.63	16.51	13.25	15.70	15.61
Hg	0.09	0.08	0.02	0.01	0.01	0.01	0.01
Ni	95.88	68.56	30.28	23.31	20.50	19.92	20.98
Pb	66.90	17.17	14.06	4.62	4.55	6.71	7.26
Se	0.80	0.86	0.49	0.77	0.82	0.73	0.86
Zn	1630.64	1184.26	72.24	54.11	47.01	55.30	44.63

(continued)

TABLE 16.(continued)

Boring and sample	2C1	2C2	2C3	2C4	2C5	2C6	2C7
Elevation (m)			256.51	255.60	254.38	253.45	251.40
Depth below sludge/soil interface (m)			0.08	0.99	2.21	3.14	5.55
Ht. above water table (m)			4.31	3.22	2.00	1.07	-1.34
Conc. (mg/kg dry wt.)							
Fe	26272.88	17532.36	15162.99	20867.45	13576.87	8662.46	9075.01
K	266.41	1330.04	483.10	773.94	735.41	435.69	339.28
Mn	626.08	479.58	1084.29	439.32	319.58	239.66	293.43
Na	330.25	1439.87	357.92	206.91	180.08	102.61	119.60
B	36.82	11.88	5.31	10.56	11.02	6.96	7.14
Be	0.44	0.45	0.54	0.67	0.37	0.29	0.22
Cd	2.84	2.25	1.55	2.43	1.73	1.16	1.13
Cr	98.66	30.99	12.92	15.99	11.65	9.31	12.70
Cu	16.82	20.35	11.11	24.30	17.06	15.34	11.54
Hg	0.02	0.07	0.03	0.02	0.02	0.01	0.00
Ni	54.13	27.40	13.92	32.22	24.50	17.95	13.01
Pb	10.99	18.09	14.06	9.64	7.50	6.73	5.94
Se	1.12	0.84	0.46	0.67	1.77	0.18	0.21
Zn	1048.46	229.73	48.22	79.24	60.06	52.65	38.85

TABLE 17. ANALYSES OF NITRIC ACID DIGESTS OF SOIL SAMPLES FROM CONTROL BORINGS AT SITE X

Boring and sample	3C1	3C2	3C3	4C1	5C1	5C2
Elevation (m)	285.35	284.45	282.19	285.45	285.83	284.91
Ht. above water table (m)	1.97	1.07	-1.19	2.08	2.45	1.53
Conc. (mg/kg dry wt.)						
Fe	22852.51	35987.73	11.32	22466.78	17202.49	18357.78
K	912.40	719.75	565.90	572.06	867.44	637.19
Mn	619.06	673.07	238.08	599.77	933.33	453.61
Na	85.27	44.98	154.56	95.01	25.62	151.60
B	17.14	17.31	21.19	9.06	8.15	27.36
Be	0.78	0.98	0.36	0.46	0.41	0.34
Cd	3.34	3.14	1.48	7.99	2.10	1.92
Cr	42.42	36.28	12.78	76.85	17.52	15.10
Cu	25.84	32.17	12.09	93.43	38.25	41.10
Hg	0.02	0.03	0.02	0.03	0.02	0.03
Ni	24.43	78.72	16.64	20.64	14.96	24.10
Pb	12.79	12.73	8.72	13.86	12.81	11.84
Se	1.02	0.28	0.45	1.19	1.17	0.99
Zn	72.48	30.30	45.87	77.89	59.02	98.54

(continued)

TABLE 17. (continued)

Boring and sample	6C1	6C2	7C1	7C2	8C1	9C1
Elevation (m)	285.56	284.66	285.52	284.59	285.55	285.19
Ht. above water table (m)	2.18	1.28	2.22	1.29	2.19	2.11
Conc. (mg/kg dry wt.)						
Fe	14961.01	40577.16	13444.79	23916.70	20850.39	16176.78
K	473.20	907.77	388.71	347.03	562.01	385.75
Mn	578.27	814.27	364.90	487.68	754.38	723.48
Na	59.68	47.20	55.79	34.70	37.91	105.77
B	7.92	15.16	4.52	7.87	7.77	5.93
Be	0.36	1.05	0.36	0.59	0.46	0.44
Cd	1.50	3.33	BDL	0.03	0.44	5.44
Cr	10.46	19.74	7.79	17.58	25.45	95.95
Cu	25.97	34.86	35.21	20.54	22.08	80.08
Hg	0.02	0.02	0.01	0.03	0.02	0.02
Ni	14.83	46.16	10.75	19.27	16.35	13.73
Pb	10.09	18.16	10.06	12.19	13.27	11.55
Se	1.14	1.04	0.48	BDL	0.52	0.59
Zn	61.10	125.27	45.18	72.22	56.58	61.24

BDL = Below detection limits.

TABLE 18. ANALYSES OF NITRIC ACID DIGESTS OF SOIL SAMPLES FROM EXPERIMENTAL BORINGS AT SITE X

Boring and sample	1C1	1C2	2C1	2C2
Elevation (m)		285.32		285.33
Depth below sludge/soil interface (m)		0.09		0.07
Ht. above water table (m)		2.65		2.40
Conc. (mg/kg dry wt.)				
Fe	3494.40	22579.62	4579.29	23090.18
K	50.74	837.14	125.63	950.77
Mn	90.47	498.00	128.66	600.54
Na	952.58	664.89	1610.86	883.97
B	30.73	13.12	40.12	15.46
Be	0.69	0.49	0.90	0.70
Cd	109.14	2.44	102.32	2.76
Cr	1493.45	14.14	1783.04	18.08
Cu	1531.79	28.20	1772.95	26.56
Hg	0.26	0.04	0.17	0.03
Ni	42.65	26.28	56.28	21.36
Pb	18.19	11.60	21.28	11.89
Se	0.45	0.22	2.12	0.27
Zn	413.58	67.47	481.23	84.36

TABLE 19. ANALYSES OF NITRIC ACID DIGESTS OF SOIL SAMPLES FROM CONTROL BORINGS AT SITE Y

Boring and sample	3C1	3C2	3C3	3C4	3C5	4C1	4C2	4C3
Elevation (m)	186.94	186.02	185.26	184.13	181.43	186.92	185.99	185.23
Ht. above water table (m)	9.82	8.90	8.14	7.01	4.31	9.53	8.60	7.84
Conc. (mg/kg dry wt.)								
Fe	24269.17	36164.67	27242.40	20723.46	17832.90	20436.30	25864.15	19465.27
K	763.01	562.86	1375.61	731.66	422.36	519.28	318.48	489.08
Mn	561.66	530.03	210.36	225.82	335.99	409.55	283.75	346.25
Na	86.41	43.43	115.98	93.04	90.10	229.49	153.45	89.99
B	11.49	13.03	14.20	10.40	7.48	7.87	8.59	9.39
Be	0.65	1.20	0.87	0.52	0.10	0.59	0.82	0.44
Cd	0.28	1.36	0.73	0.22	1.48	1.76	2.08	1.84
Cr	12.09	14.76	17.40	10.19	7.47	11.47	13.70	10.37
Cu	21.79	30.05	26.25	22.16	21.92	17.14	18.10	22.16
Hg	0.02	0.02	0.08	0.20	0.12	0.02	0.21	0.02
Ni	31.12	34.52	34.39	23.98	19.46	24.65	25.31	27.12
Pb	10.11	9.75	8.99	8.46	8.45	9.21	7.72	8.80
Se	0.10	BDL	BDL	BDL	BDL	0.24	BDL	BDL
Zn	65.27	80.57	68.78	74.35	60.72	55.86	61.96	63.09

(continued)

TABLE 19. (continued)

Boring and sample	4C4	4C5	4C6	4C7	5C1	5C2	5C3	5C4
Elevation (m)	183.87	181.43	179.23	177.16	186.64	185.73	184.97	183.58
Ht. above water table (m)	6.48	4.04	1.84	-0.23	9.74	8.83	8.07	6.68
Conc. (mg/kg dry wt.)								
Fe	20435.79	17808.00	17740.80	19266.13	19305.95	13473.95	13749.88	26527.58
K	937.01	926.38	858.58	628.68	807.70	294.92	344.26	700.06
Mn	280.19	325.56	242.85	298.27	477.90	481.46	709.88	445.77
Na	103.52	98.03	96.77	96.33	111.67	63.13	81.48	72.65
B	12.05	11.42	12.33	9.72	12.49	5.54	6.19	11.23
Be	0.53	0.48	0.37	0.30	0.62	0.47	0.55	0.59
Cd	1.99	1.65	1.80	1.54	2.00	1.32	1.27	2.57
Cr	13.21	11.87	8.66	8.70	15.62	9.42	0.97	10.79
Cu	23.88	25.60	19.12	18.13	54.95	7.28	11.06	32.65
Hg	0.02	0.01	BDL	0.02	0.05	0.10	0.06	0.02
Ni	35.72	25.03	25.07	22.08	23.88	12.18	13.68	37.02
Pb	10.71	7.20	9.49	8.45	18.93	5.65	7.13	12.11
Se	BDL	BDL	BDL	BDL	0.18	BDL	BDL	BDL
Zn	63.90	52.61	74.28	77.49	149.53	46.83	46.75	132.09

(continued)

TABLE 19 (continued)

Boring and sample	5C5	5C6	5C7	6C6	7C5	8C1	8C2	8C3
Elevation (m)	181.14	179.01	176.86	179.09	177.06	186.55	185.62	183.45
Ht. above water table (m)	4.24	2.11	-0.04	2.14	-2.01	9.01	8.08	5.91
Conc. (mg/kg dry wt.)								
Fe	24518.92	16899.77	17360.29	13259.11	21145.56	22177.23	10968.34	14555.71
K	633.10	687.07	434.01	272.60	503.15	439.74	293.14	276.47
Mn	374.64	228.08	309.08	128.86	268.04	521.54	179.51	347.82
Na	67.70	44.33	114.32	53.78	68.91	134.20	119.39	33.87
B	8.69	7.76	14.82	3.18	8.18	3.24	2.84	3.91
Be	0.55	0.46	0.23	0.25	0.35	0.36	0.30	0.38
Cd	1.98	1.52	2.94	1.46	5.28	1.37	1.73	1.84
Cr	9.42	0.02	9.88	6.78	10.52	8.96	7.50	5.83
Cu	25.58	18.89	26.21	16.47	22.75	9.33	9.61	17.58
Hg	0.18	0.42	0.22	0.52	0.02	0.03	0.02	0.01
Ni	31.86	22.74	30.09	18.39	31.08	15.35	13.33	17.05
Pb	10.98	9.23	8.74	6.49	9.44	9.52	5.82	6.41
Se	BDL	BDL	BDL	BDL	0.15	0.55	BDL	BDL
Zn	85.63	63.72	134.44	59.34	103.70	52.87	55.47	63.67

(continued)

TABLE 19 (continued)

Boring and sample	8C4	8C5	8C6	9C1	9C2	9C3	9C4
Elevation (m)	181.04	178.91	177.06	186.66	185.74	185.00	183.63
Ht. above water table (m)	3.05	1.37	-0.48	9.82	8.90	8.61	6.79
Conc. (mg/kg dry wt.)							
Fe	17877.82	22857.84	17456.36	21687.46	11310.70	21324.99	20166.66
K	752.75	48.74	468.10	842.40	225.24	1028.17	1100.99
Mn	262.46	343.75	84.77	436.38	87.89	471.19	394.55
Na	64.92	53.40	45.59	673.03	86.78	96.15	109.01
B	9.24	10.68	5.87	9.23	3.62	11.04	11.12
Be	1.13	0.43	0.37	0.72	0.36	0.64	2.77
Cd	2.29	1.90	1.38	1.78	0.60	1.84	2.05
Cr	10.20	10.62	6.70	14.20	9.79	14.32	12.69
Cu	21.17	28.95	20.12	18.19	7.98	19.32	19.62
Hg	0.02	0.02	0.02	0.03	0.02	0.02	0.01
Ni	28.35	34.78	23.83	25.84	9.97	26.59	28.05
Pb	9.41	11.24	7.78	8.96	2.85	7.62	8.72
Se	0.12	BDL	BDL	BDL	BDL	0.19	0.05
Zn	68.92	87.26	80.67	62.96	39.44	59.64	66.44

BDL = Below detection limits.

TABLE 20. ANALYSES OF NITRIC ACID DIGESTS OF SOIL SAMPLES FROM EXPERIMENTAL BORINGS AT SITE Y

Boring and sample	1C1	1C2	1C3	2C1	2C2	2C3	2C4	2C5	2C6
Elevation (m)	186.55	185.67	184.91	186.85	185.92	185.19	183.79	181.21	179.21
Depth below sludge/soil interface (m)**									
Ht. above water table (m)	1.35	0.47	-0.29	9.68	8.75	8.02	6.62	4.04	2.04
Conc. (mg/kg dry wt.)									
Fe	15877.04	9403.42	20457.00	24215.85	21591.43	21366.44	22986.16	19866.21	17554.88
K	331.73	110.63	911.11	1114.84	369.45	972.08	961.24	562.88	566.45
Mn	650.13	134.57	299.09	494.34	302.25	255.02	327.63	270.37	176.54
Na	1800.58	262.74	97.13	2147.44	369.45	97.21	109.50	71.74	75.53
B	9.05	3.60	10.66	10.51	6.52	10.78	10.62	8.02	7.55
Be	0.46	0.18	0.41	0.71	0.33	0.27	0.27	0.42	0.45
Cd	0.03	BDL	0.04	0.26	BDL	0.19	0.49	BDL	BDL
Cr	45.28	11.11	15.51	13.66	11.85	14.48	10.91	5.99	5.81
Cu	17.12	9.50	20.89	18.09	13.63	19.34	21.56	20.20	18.17
Hg	0.02	0.02	BDL	0.02	0.02	0.02	0.01	0.01	0.01
Ni	36.68	9.36	28.58	24.08	20.68	25.26	25.62	20.69	20.06
Pb	70.96	5.43	8.60	12.79	4.80	7.70	8.36	8.83	9.18
Se	0.67	BDL	BDL	0.59	BDL	BDL	BDL	BDL	BDL
Zn	353.02	55.96	60.60	63.24	65.54	65.16	69.54	78.58	68.08

BDL = Below detection limits.

** = Sludge removed at this site.

TABLE 21. ANALYSES OF NITRIC ACID DIGESTS OF SOIL SAMPLES FROM CONTROL BORINGS AT SITE Z

Boring and sample	4C1	4C2	4C3	4C4	4C5	5C1	5C2	5C3
Elevation (m)	1.99	1.03	-0.14	-1.05	-2.58	2.15	1.24	0.02
Ht. above water table (m)	0.65	-0.24	-1.48	-2.39	-3.92	0.99	0.08	-1.14
Conc. (mg/kg dry wt.)								
Fe	20880.57	18826.87	16938.52	13209.13	16241.00	20992.32	18581.89	20227.31
Mn	576.07	182.58	136.22	131.17	272.77	491.73	413.56	288.16
Na	860.39	938.50	689.19	720.58	536.58	679.61	788.06	829.41
B	5.40	5.18	4.80	3.43	3.33	4.02	4.50	5.09
Be	1.17	1.10	0.85	1.16	0.88	1.06	1.08	1.15
Cd	2.47	2.08	1.88	1.57	1.88	2.40	2.23	2.26
Cr	17.18	14.98	15.08	12.32	11.87	16.61	15.37	19.79
Cu	13.89	12.68	9.95	7.01	9.87	15.72	14.01	14.96
Hg	CI	CI	CI	BDL	BDL	CI	BDL	BDL
Ni	23.28	18.43	14.41	17.20	18.56	23.85	22.95	21.69
Pb	34.63	23.32	22.63	19.54	23.64	31.58	28.82	28.77
Se	1.27	1.07	0.96	0.93	0.94	0.56	0.70	0.70
Zn	54.42	46.81	38.52	33.41	44.66	55.19	52.58	58.53

(continued)

TABLE 21 (continued)

Boring and sample	5C4	5C5	6C1	6C2	6C3	6C4	6C5	6C6
Elevation (m)	-0.90	-2.42	2.06	1.14	-0.08	-0.99	-2.52	-4.04
Ht. above water table (m)	-2.06	-3.58	0.93	0.01	-1.21	-2.11	-3.65	-5.17
Conc. (mg/kg dry wt.)								
Fe	15093.02	12363.93	22073.16	20138.13	23213.19	21385.59	21547.15	26061.62
Mn	87.74	112.23	585.03	377.34	223.12	192.19	29.53	1040.64
Na	621.27	408.62	694.42	896.80	762.98	713.76	345.80	301.34
B	2.75	2.54	4.50	5.26	6.62	4.54	5.11	6.03
Be	0.55	0.79	1.07	1.20	1.02	1.14	1.04	1.15
Cd	1.60	1.46	2.43	2.38	2.78	2.54	2.53	3.13
Cr	15.47	11.25	18.59	20.07	27.11	20.51	20.10	19.84
Cu	7.73	9.91	14.84	15.15	11.43	10.30	10.25	13.57
Hg	BDL	BDL	BDL	BDL	0.00	BDL	BDL	0.01
Ni	9.11	14.45	24.40	23.79	17.08	16.13	16.40	21.16
Pb	16.28	14.16	33.84	36.84	24.43	19.81	15.86	37.96
Se	0.71	0.45	0.59	0.56	0.59	0.56	0.68	0.74
Zn	34.38	31.72	60.82	61.80	50.90	46.81	54.54	54.00

(continued)

TABLE 21 (continued)

Boring and sample	7C1	7C2	7C3	7C4	7C5	8C5	9C5	10C2
Elevation (m)	1.98	1.07	-0.15	-1.06	-2.59	-2.81	-2.55	1.11
Ht. above water table (m)	0.96	0.05	-1.17	-2.08	-3.61	1.03	6.67	2.71
Conc. (mg/kg dry wt.)								
Fe	26560.80	20633.29	17637.50	19919.02	21003.51	18402.23	22972.47	27836.84
Mn	253.22	176.46	269.64	182.28	379.50	497.11	222.27	283.19
Na	1182.38	988.23	626.64	606.46	404.74	832.02	544.08	1026.48
B	6.87	4.99	4.61	5.31	4.95	2.88	4.82	6.31
Be	1.48	1.04	0.83	2.19	1.00	0.85	1.00	1.44
Cd	3.15	2.60	2.25	2.59	2.77	2.54	3.14	3.56
Cr	29.83	20.30	16.22	18.61	19.14	13.28	14.35	19.55
Cu	15.23	12.94	9.33	10.94	12.98	8.16	8.99	11.50
Hg	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ni	22.45	18.17	14.40	18.21	20.98	12.63	15.05	16.51
Pb	26.23	22.31	24.46	25.56	20.06	29.61	32.32	27.11
Se	0.55	0.83	0.80	0.84	0.84	0.79	0.70	0.68
Zn	70.23	53.82	40.26	47.37	45.41	35.39	38.39	53.72

BDL = Below detection limits.

CI = Chemical interference.

TABLE 22. ANALYSES OF NITRIC ACID DIGESTS OF SOIL SAMPLES FROM EXPERIMENTAL BORINGS AT SITE Z

Boring and sample	1C1	1C2	1C3	1C4	1C5	1C6	1C7	1C8	2C1	2C2
Elevation (m)	5.61	4.09	2.46	1.54	0.32	-0.59	-2.12	-3.64	5.17	3.64
Depth below sludge/soil interface (m)	-3.05	-1.53	0.10	1.02	2.24	3.15	4.68	6.20	-3.05	-1.52
Ht. above water table (m)	5.15	3.63	2.00	1.08	-0.14	-1.05	-2.58	-4.10	4.03	2.50
Conc. (mg/kg dry wt.)										
Fe	8230.47	15804.15	24469.34	24149.29	18865.61	16047.70	13435.52	13105.36	7559.94	15823.24
Mn	60.80	267.84	614.57	291.68	283.44	1381.88	78.39	23.08	89.77	292.27
Na	163.28	1007.77	713.23	1138.33	987.39	755.13	597.53	241.28	162.78	448.49
B	1.93	5.00	6.96	7.60	6.45	6.75	4.22	4.24	2.11	3.81
Be	0.48	1.30	1.91	1.92	1.66	1.49	1.37	0.95	0.39	0.99
Cd	1.05	2.45	2.84	2.89	2.39	2.42	1.74	1.73	1.08	1.99
Cr	12.69	742.93	24.12	22.38	18.80	17.41	14.52	9.22	20.58	212.58
Cu	4.98	139.57	15.17	16.76	14.27	12.93	8.01	7.95	8.02	48.68
Hg	0.09	10.97	0.01	BDL	BDL	BDL	0.01	BDL	0.24	2.29
Ni	4.96	21.74	25.40	25.27	20.91	30.47	14.30	11.87	5.60	16.81
Pb	92.43	4751.46	36.18	29.12	29.42	33.12	14.28	15.93	15.73	2328.08
Se	0.13	0.54	0.86	0.66	0.30	0.87	0.52	0.34	0.50	0.78
Zn	19.80	442.28	54.04	68.16	57.04	51.69	38.96	27.28	33.20	149.14

continued

TABLE 22 (continued)

Boring and sample	2C3	2C4	2C5	2C6	3C1	3C2	3C3	3C4	3C5	3C6
Elevation (m)	2.01	1.10	-0.12	-1.04	5.14	3.61	1.98	1.07	-0.15	-1.07
Depth below sludge/soil interface (m)	0.11	1.02	2.24	3.16	-3.05	-1.52	0.11	1.02	2.24	3.16
Ht. above water table (m)	0.87	-0.04	-1.26	-2.18	6.10	4.57	2.94	2.03	0.18	-0.11
Conc. (mg/kg dry wt.)										
Fe	21350.54	20433.11	21178.35	19583.95	10935.74	18975.67	14570.30	20138.28	18907.56	15161.72
Mn	364.20	211.96	195.55	76.26	337.92	266.86	103.07	149.16	228.34	120.55
Na	860.78	966.28	748.00	681.84	383.65	2554.94	1240.95	1232.54	1033.98	743.47
B	5.51	6.10	5.98	4.94	3.31	10.56	3.38	5.50	5.22	3.69
Be	1.13	1.17	1.06	1.25	0.75	1.14	1.00	1.08	1.05	1.06
Cd	2.42	2.22	2.25	1.97	1.50	3.69	1.59	2.21	2.24	1.78
Cr	20.12	20.84	19.67	19.79	75.68	1926.84	14.70	16.90	16.19	13.18
Cu	16.71	13.94	13.70	10.33	23.57	200.16	11.89	13.89	12.88	0.88
Hg	0.01	BDL	BDL	0.01	0.73	5.13	0.02	CI	CI	BDL
Ni	23.94	21.75	20.44	18.58	13.43	35.68	15.84	19.65	18.89	17.24
Pb	51.44	26.02	25.01	20.98	537.78	2806.02	18.98	21.86	26.90	19.13
Se	0.40	0.64	0.86	0.84	0.75	1.16	0.37	0.52	0.48	0.55
Zn	63.45	59.94	53.69	48.76	82.44	975.22	45.27	49.95	50.49	34.96

TABLE 23. RESULTS OF RANDOMIZATION TEST OF NITRIC ACID DIGESTS OF SOIL SAMPLES DIRECTLY UNDER THE DISPOSAL SITES AND AT COMPARABLE ELEVATIONS OUTSIDE THE SITE

	W	X	Y	Z
Fe	NS	NS	NS	NS
K	NS	NS	NS	ND
Mn	S	NS	NS	NS
Na	S	S	S	NS
B	NS	NS	NS	NS
Be	NS	NS	NS	NS
Cd	NS	NS	SS	NS
Cr	NS	NS	NS	NS
Cu	NS	NS	NS	NS
Hg	NS	S	SS	ND
Ni	NS	NS	NS	NS
Pb	NS	NS	NS	NS
Se	S	SS	NS	NS
Zn	NS	NS	NS	NS

S = Level of constitent significantly larger under the disposal site at a 90% level of significance.

SS = Significantly small.

NS = Level of constituent not significantly larger or smaller under the disposal site at a 90% level of significance.

ND = Not determined.

Selenium was not present in detectable quantities in any of the deeper soil samples collected under the waste location at Site Y (Table 20, 1C2, 1C3, 2C2-2C6). Background levels for selenium in soils around the disposal site were generally low.

Site Z contains treated refinery sludge which had been covered with 0.5 m of clay. Three experimental borings were drilled through the cover material and the treated sludge to the water table (Table 22). The major pollutants at this site are chromium, copper, mercury, lead, and zinc. Slightly elevated levels of boron, cadmium, and sodium were also detected in experimental boring No. 3. The top samples in each of the experimental borings (1C1, 2C1, and 3C1) reflect the composition of the covering clay layer and bear little relation to either the treated sludge sample or the underlying soils. The second sample from each boring (sample 1C2, 2C2, and 3C2) contained a large portion of the treated sludge as can be noted by the high concentrations of the potential pollutants. However, the levels of all potential pollutants in the third sample down each experimental hole (samples 1C3, 2C3, and 3C3) are all within the range of these constituents in the surrounding soils even though these samples were taken only 10 to 12 cm below the sludge/soil interface. In only one case (lead in sample 2C3) is any sample from an experimental boring above the range observed in surrounding soils. No significant loss of pollutants to the soil under the treated sludge disposal area was detected when samples from below the disposal pit were compared to surrounding soils at similar elevations (Table 23).

The soils at all four sites have concentrations for the constituents tested which fall within the typical concentration ranges for soils in a natural state in the eastern United States (Table 24). All of the soils have concentrations near to or below the average for such soils. Even in the cases where significant increases in the constituents under the treated sludge were found, these elevated levels were always well within typical ranges for eastern soils. For instance, sodium, which was found at levels of 357,883, and 2147 mg/kg dry weight of soil under the sludges at sites W, X, and Y, respectively, has an average concentration in eastern soils of 2600 mg/kg--higher than any "contaminated" sample found.

Three of these significantly contaminated soils samples taken at the sludge/soil interface - selenium at site W, iron and nickel at site Y - had maximum value less than twice the average soil concentration and well within typical ranges. In the "worst case" noted, that of manganese contamination, at site W, the highest contaminant level was less than four times the average, and was still well within typical ranges for manganese in eastern soils. Even in the cases where significant contamination was found, appreciable degradation of the soil below that of typical eastern soil could not be demonstrated.

TABLE 24. AVERAGES AND RANGES IN COMPOSITION FOR SOILS IN THE EASTERN UNITED STATES

Constituent	Concentration*	
	Average	Range
Fe	15,000**	100 - >100,000
K	7,400	50 - 370,000
Mn	290	<2 - 7,000
Na	2,600	<200 - 15,000
B	32	<10 - 150
Be	0.6	<1 - 7
Cd	<1	<1 - 4
Cr	36	1 - 100
Cu	13	3 - 100
Hg	0.096	0.01 - 3.4
Ni	13	<3 - 700
Pb	14	<7 - 300
Se	0.39	<0.1 - 1.4
Zn	36	<5 - 400

* Concentrations are in milligrams per kilogram dry wt of soil.

** Soil analyses are for Eastern U. S. soils from ref. 13.

CHEMICAL ANALYSIS OF DISTILLED WATER EXTRACTS

The chemical analyses of distilled water extracts from soil samples are summarized in Tables 25-32. The soils at all four sites are very thoroughly weathered and the rate of release of normal soil constituents into the distilled water extract was extremely low. In many cases the background levels for distilled water extracts were in the low part per billion range and often they were below the minimum detectable concentration using conventional analytical techniques. The soils at all four sites are very well weathered and there are few leachable constituents. The treated waste, in contrast, contains lime and soluble sodium compounds used in the solidification process as well as the normal soluble materials in the sludge.

A randomization test was used to determine if statistically significant (90% level of significance) differences could be observed in distilled water extracts of soil sample directly below the disposal sites and soils collected from comparable elevations outside the disposal area. The results are presented in Table 33.

At Site W, an auto assembly facility, most anions and toxic metals were present in small quantities in distilled water extracts from soil collected below the disposal site. The materials present in amounts that would cause concern with regard to possible healths effects are; sulfate, iron, chromium and selenium.(Table 24, 1C3, 2C3). All of these were present in the waste (Table 2) and are extractable at levels above the standards for public water supplies (14).

At Site X, where treated electroplating waste were disposed, unacceptable levels of sulfate, iron, manganese, arsenic, beryllium, chromium, lead and selenium were found (Table 28, 1C2, 2C2). Most of these contaminants can be attributed to the landfilled wastes (Table 2).

At Site Y, where paint and putty from auto assembly activities were treated and landfilled soil extracts under the waste showed unacceptable levels of iron, manganese, sodium, arsenic, chromium and lead (Table 30). In all cases the maximum concentration obtained below the site is much larger than the maximum concentration obtained from background soil samples.

At Site Z, where an oily refinery sludge had been treated and landfilled only phenol appeared in unacceptable levels in the distilled water extracts (Table 32). The lack of extractable pollutants in the soil may have been related to the hydrophobic nature of the treated waste or possibly the use of a clay cover over the disposal area.

The constituents found in appreciable concentrations in the distilled water extracts are those materials that would be easily removed from the soil by natural leaching by rainwater. These constituents are not tightly bound to the soil and could be considered as potentially migrating into the groundwater. The discovery of high levels (above standards for public water supplies) of phenol and toxic metals (chromium, lead, selenium) in distilled water extracts from soil collected from under the treated waste suggests that in the future higher levels of the pollutants may appear in ground or surface

TABLE 25. ANALYSES OF DISTILLED WATER EXTRACTS OF SOIL SAMPLES FROM CONTROL BORINGS AT SITE W

Boring and sample	3C1	3C2	3C3	3C4	3C5	3C6	4C6	5C1
Elevation (m)	256.84	255.93	254.71	253.81	251.20	249.37	250.75	256.68
Ht. above water table (m)	6.16	5.25	4.03	3.13	0.52	-1.31	-1.02	5.63
Conc. (mg/ℓ)								
SO_4	86	46	56	10	4	25	20	96
SO_3	<1	<1	<1	<1	<1	<1	<1	<1
Cl	<5	<5	<5	<5	<5	<5	<5	<5
NO_3-N	0.09	0.10	0.04	0.01	0.03	0.02	0.06	0.03
NO_2-N	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CN	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TOC	12	<1	2	1	4	9	12	17
Ca	25.90	17.80	11.10	12.60	17.80	28.70	13.10	44.40
Fe	ND	ND	0.030	0.140	ND	ND	ND	ND
Mg	5.70	8.00	6.00	4.60	6.80	9.40	4.90	10.80
Mn	0.002	0.001	0.002	<0.001	0.020	0.028	0.033	0.003
Na	4.10	2.20	2.00	2.20	0.70	1.00	0.30	7.70
As	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
B	0.05	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.269
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Cr	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Cu	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Hg	0.0004	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Ni	0.011	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Pb	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Se	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	<0.005
Zn	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014

(continued)

Note: ND = Not determined.

TABLE 25 (continued)

Boring and sample	5C6	6C1	6C5	7C1	7C2	7C3	7C4	7C5	8C6
Elevation (m)	250.60	257.07	252.68	255.21	255.21	253.99	253.07	251.55	250.55
Ht. above water table (m)	-0.45	2.33	-2.06	2.82	2.06	0.84	-0.07	-1.60	1.33
Conc. (mg/ℓ)									
SO_4	76	456	86	86	96	22	20	21	<8
SO_3	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cl	<5	<5	15	<5	<5	<5	<5	<5	<5
NO_3-N	0.04	0.04	<0.01	0.40	0.15	0.01	0.02	0.03	<0.01
NO_2-N	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CN	<0.01	<0.01	<0.01	ND	ND	ND	ND	ND	ND
TOC	18	4	3	4	1	2	9	11	20
Ca	28.40	150.00	14.80	30.80	22.40	11.50	10.90	12.60	17.80
Fe	ND	ND	ND	0.180	ND	ND	ND	ND	ND
Mg	10.80	17.10	7.80	4.30	13.20	7.80	7.30	6.60	7.00
Mn	0.046	0.015	0.012	0.002	<0.001	<0.001	0.001	0.008	0.011
Na	3.40	7.10	10.00	9.00	3.40	1.10	0.60	0.40	0.70
As	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
B	0.03	0.68	0.17	0.05	<0.02	<0.02	<0.02	<0.02	<0.02
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Cr	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Cu	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Hg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Ni	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Pb	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Se	<0.005	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.015	0.006
Zn	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014

TABLE 26. ANALYSES OF DISTILLED WATER EXTRACTS OF SOIL SAMPLES FROM EXPERIMENTAL BORINGS AT SITE W

Boring and sample	1C1	1C2	1C3	1C4	1C5	1C6	1C7
Elevation (m)			255.87	254.94	253.73	252.79	250.54
Depth below sludge/ soil interface (m)			0.07	1.00	2.21	3.15	5.40
Ht. above water table (m)			2.49	1.56	0.35	-0.59	-2.84
Conc. (mg/ℓ)							
SO_4	1296	646	1796	51	24	29	41
SO_3	<1	<1	<1	<1	<1	<1	<1
Cl	<5	35	15	<5	<5	<5	<5
NO_3-N	0.02	0.02	0.05	0.04	0.10	0.14	0.02
NO_2-N	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CN	0.02	0.06	<0.01	<0.01	<0.01	<0.01	<0.01
TOC	52	26	6	18	4	9	5
Ca	562.00	87.70	17.20	17.70	13.40	25.10	28.20
Fe	ND	0.260	ND	ND	0.220	ND	ND
Mg	0.90	ND	9.00	6.80	6.00	6.00	9.70
Na	41.80	418.00	28.10	3.40	4.60	0.80	0.60
As	0.008	<0.003	0.007	<0.003	<0.003	<0.003	<0.003
B	0.04	<0.02	0.03	<0.02	<0.02	<0.02	<0.02
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Cr	0.017	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Cu	0.020	0.014	<0.003	<0.003	<0.003	<0.003	<0.003
Hg	<0.0002	<0.0002	<0.0004	<0.0002	<0.0002	<0.0004	0.0002
Ni	0.019	0.244	0.005	<0.005	<0.005	<0.005	<0.005
Pb	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Se	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zn	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014

(continued)

Note: ND = Not determined.

TABLE 26 (continued)

Boring and sample	2C1	2C2	2C3	2C4	2C5	2C6	2C7
Elevation (m)			256.51	255.60	254.38	253.45	251.04
Depth below sludge/ soil interface (m)			0.08	0.99	2.21	3.14	5.55
Ht. above water table (m)			4.13	3.22	2.00	1.07	-1.34
Conc. (mg/ℓ)							
SO_4	1446	446	196	76	86	23	46
SO_3	<1	45	15	<1	<1	<1	<1
Cl	<5	<5	<5	<5	<5	<5	<5
NO_3-N	0.18	0.02	0.05	0.03	0.04	0.11	0.05
NO_2-N	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01
CN^-	<0.01	0.02	0.01	ND	<0.01	<0.01	<0.01
TOC	56	32	25	ND	2	10	1
Ca	593.00	66.20	1.40	25.00	19.00	13.20	23.70
Fe	ND	0.100	33.000	ND	ND	ND	ND
Mg	2.60	ND	3.60	11.30	6.50	6.90	8.40
Mn	0.029	0.001	2.700	0.001	<0.001	<0.001	0.034
Na	17.90	168.00	49.30	22.30	15.50	0.90	7.10
As	<0.003	<0.003	0.041	<0.003	0.005	<0.003	<0.003
B	0.27	<0.02	0.05	<0.02	<0.02	<0.02	<0.02
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	<0.0003	<0.0003	0.0025	<0.0003	<0.0003	<0.0003	<0.0003
Cr	0.008	0.004	0.056	<0.003	<0.003	<0.003	<0.003
Cu	0.003	0.004	0.047	<0.003	<0.003	<0.003	<0.003
Hg	<0.0002	<0.0002	0.0002	0.0002	<0.0002	<0.0002	<0.0002
Ni	<0.005	0.160	0.084	<0.005	<0.005	<0.005	<0.005
Pb	<0.002	<0.002	0.026	<0.002	<0.002	<0.002	<0.002
Se	0.005	0.005	0.013	<0.005	<0.005	<0.005	0.005
Zn	0.022	<0.014	0.261	<0.014	<0.014	0.019	<0.014

TABLE 27. ANALYSES OF DISTILLED WATER EXTRACTS OF SOIL SAMPLES FROM CONTROL BORINGS AT SITE X

Boring and sample	3C1	3C2	3C3	4C1	5C1	5C2
Elevation (m)	285.35	284.45	282.19	285.45	285.83	284.91
Ht. above water table (m)	1.97	1.07	-1.19	2.08	2.45	1.53
Conc. (mg/ℓ)						
SO_4	9	24	14	3	29	<8
SO_3	<1	<1	<1	<1	<1	<1
Cl	<5	<5	<5	<5	<5	<5
NO_3-N	2.13	0.49	0.02	1.53	2.85	0.10
NO_2-N	0.02	0.01	0.01	0.03	<0.01	<0.01
CN	0.02	ND	<0.01	0.02	<0.01	<0.01
TOC	8	ND	5	8	12	6
Ca	23.20	6.80	33.60	23.60	13.20	10.90
Fe	0.185	0.410	ND	0.180	2.310	0.831
Mg	10.00	3.20	9.90	8.40	2.50	5.30
Mn	0.001	0.004	0.036	0.002	0.108	0.009
Na	3.90	2.00	2.00	2.60	1.30	0.70
As	0.008	0.010	0.009	0.010	0.008	0.008
B	0.03	<0.02	<0.02	0.02	0.03	0.02
Be	<0.005	<0.005	<0.005	<0.005	0.005	<0.005
Cd	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Cr	0.084	0.009	0.004	0.036	0.019	0.006
Cu	ND	ND	ND	ND	ND	ND
Hg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Ni	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Pb	<0.002	<0.002	<0.002	<0.002	<0.003	<0.002
Se	0.015	0.009	0.015	<0.005	0.015	0.014
Zn	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014

(continued)

Note: ND = Not determined.

TABLE 27 (continued)

Boring and sample	6C1	6C2	7C1	7C2	8C1	9C1
Elevation (m)	285.56	284.66	285.52	284.59	285.55	285.19
Ht. above water table (m)	2.18	1.28	2.22	1.29	2.19	2.11
Conc. (mg/ℓ)						
SO_4	<8	25	13	27	<8	13
SO_3	<1	<1	<1	<1	<1	<1
Cl	<5	<5	<5	<5	<5	<5
NO_3-N	0.25	0.15	<0.01	0.02	0.30	0.72
NO_2-N	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
CN^-	ND	0.01	0.01	<0.01	<0.01	0.01
TOC	ND	8	13	4	6	10
Ca	19.10	8.20	15.90	8.20	20.00	18.60
Fe	0.428	1.180	2.600	ND	0.902	1.720
Mg	4.60	3.20	10.60	3.10	5.10	4.50
Mn	0.004	0.011	0.037	0.018	0.014	0.037
Na	1.30	2.60	3.30	3.30	1.30	6.50
As	0.006	0.005	0.008	0.008	0.007	0.013
B	0.03	0.02	0.06	0.02	<0.02	0.03
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	0.0004
Cr	0.003	0.004	0.010	<0.003	0.015	0.051
Cu	ND	ND	ND	ND	ND	ND
Hg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Ni	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Pb	<0.002	0.004	0.005	<0.001	<0.002	0.002
Se	0.019	0.015	0.017	0.014	0.010	0.014
Zn	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014

(continued)

TABLE 28. ANALYSES OF DISTILLED WATER EXTRACTS OF SOIL SAMPLES FROM EXPERIMENTAL BORINGS AT SITE X

Boring and sample	1C1	1C2	2C1	2C2
Elevation (m)		285.32		285.33
Depth below sludge/ soil interface (m)		0.09		0.07
Ht. above water table (m)		2.65		2.40
Conc. (mg/ℓ)				
SO_4	<8	360	<8	320
SO_3	<1	<1	<1	<1
Cl	<5	<5	<5	<5
NO_3-N	0.27	0.69	0.15	0.86
NO_2-N	0.12	0.19	0.09	0.18
CN^2	0.01	0.01	0.01	0.02
TOC	12	48	22	84
Ca	511.00	26.50	630.00	17.70
Fe	ND	85.200	0.143	64.40
Mg	<0.01	3.70	<0.01	4.50
Mn	0.001	1.520	0.001	2.530
Na	54.20	44.40	96.70	54.90
As	0.005	0.200	0.010	0.150
B	0.02	0.01	0.02	0.09
Be	0.006	0.007	<0.005	0.011
Cd	<0.0003	0.0012	<0.0003	0.0010
Cr	0.082	0.079	0.078	0.098
Cu	0.167	0.240	0.164	0.278
Hg	<0.0002	0.0007	<0.0002	0.0003
Ni	<0.005	0.269	<0.005	0.209
Pb	0.005	0.044	0.007	0.079
Se	0.006	0.022	0.005	0.015
Zn	<0.014	0.813	<0.014	0.666

Note: ND = Not determined.

TABLE 29. ANALYSES OF DISTILLED WATER EXTRACTS OF SOIL SAMPLES FROM CONTROL BORINGS AT SITE Y

Boring and sample	3C1	3C2	3C3	3C4	3C5	4C1	4C2	4C3
Elevation (m)	186.94	186.02	185.26	184.13	181.43	186.92	185.99	185.23
Ht. above water table (m)	9.82	8.90	8.14	7.01	4.31	9.53	8.60	7.84
Conc. (mg/ℓ)								
SO_4	1150	450	40	40	40	90	43	100
SO_3	<1	<1	<1	<1	<1	<1	<1	<1
Cl	<5	<5	<5	<5	<5	<5	<5	<5
NO_3-N	0.19	0.37	0.03	0.01	0.03	0.22	0.05	0.03
NO_2-N	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CN	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TOC	4	2	6	4	7	6	2	<1
Ca	388.00	190.00	39.60	32.00	50.30	16.60	11.30	49.50
Fe	3.390	1.030	0.418	0.376	0.378	2.770	ND	0.183
K	1.37	0.49	0.64	0.63	3.64	0.50	ND	0.74
Mg	98.40	61.20	10.00	8.30	9.20	2.10	3.60	16.70
Mn	0.009	1.699	0.009	0.009	0.099	0.009	0.009	0.009
Na	2.30	2.90	2.90	1.90	1.20	27.00	20.40	4.70
As	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
B	0.08	<0.02	<0.02	<0.02	<0.02	0.06	0.02	<0.02
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	<0.0003	0.0021	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Cr	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Cu	ND	ND	ND	ND	ND	ND	ND	ND
Hg	<0.0002	0.0026	0.0006	0.0007	<0.0002	<0.0002	0.0032	0.0016
Ni	<0.005	0.070	0.007	0.008	0.007	0.007	<0.005	<0.005
Pb	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Se	<0.005	0.008	<0.005	<0.005	0.013	<0.005	<0.005	<0.005
Zn	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014

(continued)

Note: ND = Not determined.

TABLE 29 (continued)

Boring and sample	4C4	4C5	4C6	4C7	5C1	5C2	5C3	5C4
Elevation (m)	183.87	181.43	179.23	177.16	186.64	185.73	184.97	183.58
Ht. above water table (m)	6.48	4.04	1.84	-0.23	9.74	8.83	8.07	6.68
Conc. (mg/ℓ)								
SO_4	50	30	90	40	50	50	24	12
SO_3	<1	1	<1	2	<1	<1	<1	<1
Cl	<5	<5	<5	<5	<5	<5	<5	15
NO_3-N	0.01	0.01	0.02	0.01	0.10	0.06	0.02	0.04
NO_2-N	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01
CN	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
TOC	1	<1	12	2	8	6	2	<1
Ca	45.10	42.90	44.50	46.70	20.60	5.70	7.40	7.50
Fe	0.113	0.154	0.132	0.119	0.841	11.000	1.970	0.215
K	4.60	4.75	4.33	5.32	0.85	0.39	0.24	1.71
Mg	13.00	11.40	10.70	10.00	4.30	1.00	1.30	2.20
Mn	0.019	0.019	0.019	0.019	0.009	0.349	0.019	0.009
Na	2.30	1.20	1.00	2.30	1.50	2.60	5.60	3.80
As	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
B	<0.02	<0.02	<0.02	<0.02	0.03	0.03	0.02	<0.02
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Cr	<0.003	<0.003	<0.003	<0.003	<0.003	0.010	<0.003	<0.003
Cu	ND	ND	ND	ND	ND	ND	ND	ND
Hg	0.0011	0.0025	0.0004	0.0013	0.0023	0.0028	0.0012	<0.0002
Ni	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Pb	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	<0.002	<0.002
Se	0.007	0.005	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zn	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014

(continued)

TABLE 29 (continued)

Boring and sample	5C5	5C6	5C7	6C6	7C5	8C1	8C2	8C3
Elevation (m)	181.14	179.01	176.86	179.09	177.06	186.55	185.62	183.45
Ht. above water table (m)	4.24	2.11	-0.04	2.14	-2.01	9.01	8.08	5.91
Conc. (mg/ℓ)								
SO_4	10	6	47	23	19	100	90	27
SO_3	<1	<1	<1	<1	<1	<1	<1	<1
Cl	<5	<5	<5	<5	<5	<5	<5	<5
NO_3-N	0.13	0.22	0.04	0.17	0.05	0.16	0.07	0.07
NO_2-N	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	0.03	<0.01
CN	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
TOC	1	2	6	2	4	13	15	2
Ca	3.10	2.70	30.20	4.30	21.00	7.10	1.60	3.50
Fe	0.569	0.658	0.106	0.791	ND	20.700	15.800	2.350
K	1.33	1.16	1.86	1.03	1.24	2.43	1.19	0.58
Mg	0.70	0.70	7.50	1.30	0.70	1.70	0.40	1.20
Mn	0.019	0.009	0.009	0.019	0.009	0.599	1.699	0.009
Na	4.90	0.80	5.40	6.20	1.10	11.10	6.70	2.30
As	<0.003	<0.003	<0.003	<0.003	<0.003	0.025	0.025	0.005
B	<0.02	<0.02	<0.02	<0.02	<0.02	0.04	<0.02	<0.02
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Cr	<0.003	<0.003	<0.003	<0.003	<0.003	0.030	0.020	<0.003
Cu	ND	ND	ND	ND	ND	ND	ND	ND
Hg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Ni	<0.005	<0.005	<0.005	<0.005	<0.005	0.045	0.029	0.007
Pb	0.002	<0.002	<0.002	<0.002	<0.002	0.013	0.013	0.002
Se	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zn	<0.014	<0.014	<0.014	<0.014	<0.014	0.151	<0.014	<0.014

TABLE 30. ANALYSES OF DISTILLED WATER EXTRACTS OF SOIL SAMPLES FROM EXPERIMENTAL BORINGS AT SITE Y

Boring and sample	1C1	1C2	1C3	2C1	2C2	2C3	2C4	2C5	2C6
Elevation (m)	186.55	185.67	184.91	186.85	185.92	185.19	183.79	181.21	179.21
Ht. above water table (m)	1.35	0.47	-0.29	9.68	8.75	8.02	6.62	4.04	2.04
Conc. (mg/ℓ)									
SO_4	100	100	39	950	50	50	34	80	66
SO_3	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cl^-	40	<5	<5	<5	<5	<5	<5	<5	<5
NO_3-N	7.86	0.03	0.01	0.08	0.03	0.03	0.01	0.02	0.01
NO_2-N	0.03	0.04	<0.01	0.51	0.02	<0.01	<0.01	<0.01	<0.01
CN^-	0.09	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TOC	14	22	3	ND	10	<1	4	12	<1
Ca	25.20	4.00	29.60	21.40	3.60	22.60	25.80	48.80	29.40
Fe	1.080	30.900	ND	165.000	12.800	0.440	ND	ND	0.148
K	4.21	1.01	0.98	168.00	0.67	0.68	2.33	1.61	1.55
Mg	2.00	0.06	7.30	10.00	0.50	5.20	5.70	11.50	8.60
Mn	ND	0.929	0.019	3.629	0.089	0.019	0.019	0.009	0.009
Na	3008.00	22.80	5.50	206.00	32.40	2.10	4.80	1.00	1.00
As	0.012	0.037	<0.003	0.278	0.010	<0.003	<0.003	<0.003	<0.003
B	0.09	<0.02	<0.02	0.19	<0.02	<0.02	<0.02	<0.02	<0.02
Be	<0.005	0.008	<0.015	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	<0.0003	<0.0003	<0.0003	0.0085	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Cr	0.004	0.021	<0.003	0.576	0.018	<0.003	<0.003	<0.003	<0.003
Cu	0.037	0.046	0.022	0.656	0.022	0.032	0.037	0.015	0.023
Hg	0.0017	0.0013	<0.0002	0.0011	<0.0002	0.0021	0.0018	0.0030	<0.0002
Ni	<0.005	0.056	<0.005	0.326	0.023	<0.005	<0.005	<0.005	<0.005
Pb	0.002	0.014	<0.002	0.056	0.002	<0.002	<0.002	<0.002	<0.002
Se	<0.005	0.009	0.010	0.005	0.015	0.022	0.017	0.005	<0.005
Zn	<0.014	0.142	<0.014	0.963	<0.014	<0.014	<0.014	<0.014	<0.014

Note: ND = Not determined.

TABLE 31. ANALYSES OF DISTILLED WATER EXTRACTS OF SOIL SAMPLES FROM CONTROL BORINGS AT SITE Z

Boring and sample	4C1	4C2	4C3	4C4	4C5	5C1	5C2	5C3
Elevation (m)	1.99	1.03	-0.14	-1.05	-2.58	2.15	1.24	0.02
Ht. above water table (m)	0.65	-0.24	-1.48	-2.39	-3.92	0.99	0.08	-1.14
Conc. (mg/ℓ)								
SO_4	<8	<8	<8	<8	8	<8	18	<8
SO_3	<1	<1	<1	<1	<1	<1	<1	<1
Cl^-	60	60	30	35	50	55	50	35
NO_3-N	0.10	0.05	0.09	0.04	0.03	0.04	0.31	0.03
NO_2-N	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CN^-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TOC	7	8	9	8	7	7	9	10
Phenol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ca	7.50	5.00	4.20	4.40	3.60	6.50	4.90	2.90
Fe	ND	0.119	0.163	0.137	0.129	0.110	0.127	0.257
K	0.36	0.66	0.90	0.60	1.20	0.46	0.83	1.26
Mg	2.85	2.11	1.95	1.84	1.85	2.12	1.94	1.68
Mn	0.005	0.008	0.011	0.008	0.019	0.008	0.011	0.013
Na	83.10	79.90	65.70	62.30	51.70	69.10	71.30	64.00
As	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
B	0.18	0.13	0.05	0.03	0.02	0.08	0.09	0.07
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Cr	0.004	0.007	0.006	0.005	0.014	0.004	0.008	0.012
Cu	ND	ND	ND	ND	ND	ND	ND	ND
Hg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Ni	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Pb	0.008	0.002	<0.002	<0.002	0.002	<0.002	<0.002	0.002
Se	<0.005	<0.005	<0.005	<0.005	0.006	<0.005	<0.005	<0.005
Zn	ND	ND	ND	ND	ND	ND	ND	ND

(continued)

Note: ND = Not determined.

TABLE 31 (continued)

Boring and sample	5C4	5C5	6C1	6C2	6C3	6C4	6C5	6C6
Elevation (m)	-0.90	-2.42	2.06	1.14	-0.08	-0.99	-2.52	-4.04
Ht. above water table (m)	-2.06	-3.58	0.93	0.01	-1.21	-2.12	-3.65	-5.17
Conc. (mg/ℓ)								
SO_4	<8	<8	138	138	105	59	<8	<8
SO_3	<1	<1	<1	<1	<1	<1	<1	<1
Cl	40	35	35	25	25	35	30	20
NO_3-N	0.02	0.04	0.07	0.04	0.02	0.02	0.03	0.06
NO_2-N	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CN^2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TOC	6	7	10	13	12	10	5	10
Phenol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ca	4.30	4.80	18.50	13.00	7.90	3.30	5.70	5.00
Fe	0.113	ND	ND	ND	ND	ND	ND	ND
K	0.63	0.66	0.16	0.30	0.55	0.76	0.56	0.93
Mg	1.72	1.74	4.96	3.51	2.29	1.08	1.55	0.98
Mn	0.010	0.008	0.004	0.031	0.026	0.014	0.006	0.029
Na	61.80	48.30	87.60	85.90	79.70	59.00	44.90	38.20
As	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.014
B	0.04	0.04	0.15	0.14	0.11	0.07	0.02	0.03
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	<0.0003	<0.0003	<0.0005	0.0004	0.0003	<0.0003	<0.0003	<0.0003
Cr	0.005	0.004	<0.003	<0.003	0.004	0.005	<0.002	<0.002
Cu	ND	ND	ND	ND	ND	ND	ND	ND
Hg	<0.0002	<0.0002	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0003
Ni	<0.005	<0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Pb	0.002	<0.002	0.002	0.002	<0.002	<0.002	0.003	0.003
Se	<0.005	<0.005	<0.005	0.005	0.007	0.005	0.009	0.017
Zn	ND	ND	ND	ND	ND	ND	ND	ND

(continued)

TABLE 31 (continued)

Boring and sample	7C1	7C2	7C3	7C4	7C5	8C5	9C5	10C2
Elevation (m)	1.98	1.07	-0.15	-1.06	-2.59	-2.81	-2.55	1.11
Ht. above water table (m)	0.96	0.05	-1.17	-2.08	-3.61	1.03	6.67	2.71
Conc. (mg/ℓ)								
SO_4	25	<8	<8	<8	<8	17	<8	24
SO_3	<1	<1	<1	<1	<1	<1	<1	<1
Cl	11	12	8	9	5	9	<5	7
NO_3-N	0.07	0.01	0.01	0.07	0.02	0.44	<0.01	<0.01
NO_2-N	<0.01	0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01
CN	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TOC	7	6	6	8	8	9	11	11
Phenol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ca	7.60	6.10	6.50	5.60	7.60	3.00	3.40	3.60
Fe	ND	0.101	ND	ND	ND	0.158	0.358	0.348
K	0.29	0.46	0.41	0.40	0.60	0.61	0.66	0.54
Mg	2.64	2.17	1.98	1.65	2.27	1.62	1.76	1.94
Mn	0.004	0.007	0.019	0.020	0.014	0.006	0.018	0.008
Na	100.00	95.50	79.20	65.10	47.20	95.50	57.80	84.20
As	0.008	0.011	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
B	0.19	0.17	0.07	0.03	<0.02	0.03	0.03	0.21
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	0.0047	0.0003	0.0003
Cr	<0.003	0.003	<0.003	<0.003	<0.003	0.007	0.006	0.006
Cu	ND	ND	ND	ND	ND	ND	ND	ND
Hg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Ni	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Pb	0.004	0.002	<0.002	<0.002	0.003	<0.002	<0.002	<0.002
Se	0.010	0.010	0.012	0.010	<0.005	0.008	0.009	0.011
Zn	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 32. ANALYSES OF DISTILLED WATER EXTRACTS OF SOIL SAMPLES FROM EXPRIMENTAL BORINGS AT SITE Z

Boring and sample	1C1	1C2	1C3	1C4	1C5	1C6	1C7	1C8	2C1	2C2
Elevation (m)	5.61	4.09	2.46	1.54	0.32	-0.59	-2.12	-3.64	5.17	3.64
Depth below sludge/soil interface (m)	-3.05	-1.53	0.10	1.02	2.24	3.15	4.68	6.20	-3.05	-1.52
Ht. above water table (m)	5.15	3.63	2.00	1.08	-0.14	-1.05	-2.58	-4.10	4.03	2.50
Conc. (mg/ℓ)										
SO_4	ND	38	40	9	<8	<8	<8	<8	52	71
SO_3	<1	3	<1	<1	2	<1	<1	<1	<1	2
Cl	10	125	30	85	100	65	40	30	15	25
NO_3-N	0.13	0.08	0.06	0.04	0.13	0.15	0.10	0.06	0.06	0.16
NO_2-N	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CN	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
TOC	12	103	8	8	8	8	9	8	15	67
Phenol	<0.01	0.09	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05
Ca	17.70	12.40	12.50	6.20	6.10	5.50	5.40	5.90	22.00	42.80
Fe	ND	3.270	ND	ND	ND	ND	ND	ND	ND	0.187
K	0.75	1.77	0.12	0.48	0.51	0.64	0.64	0.57	1.14	1.35
Mg	4.16	3.55	3.62	3.03	2.78	2.58	2.03	1.71	5.23	9.81
Mn	0.004	0.069	0.006	0.005	0.005	0.007	0.004	0.009	0.051	0.165
Na	34.80	77.50	78.00	96.60	91.00	78.60	59.00	33.70	38.20	66.30
As	<0.003	0.028	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
B	<0.02	0.12	0.04	0.20	0.11	0.04	<0.02	<0.02	<0.02	0.09
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	0.0017	0.0022	0.0016	0.0017	0.0015	0.0016	0.0017	0.0017	0.0008	0.0017
Cr	0.005	0.087	0.010	0.005	0.007	0.006	0.005	<0.003	0.003	0.031
Cu	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hg	<0.0002	0.0008	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0004	0.0002	<0.0002
Ni	<0.005	0.011	<0.005	0.005	<0.005	0.005	0.005	<0.005	0.005	0.011
Pb	0.006	0.790	0.006	0.003	0.002	0.002	0.002	<0.002	0.006	0.052
Se	0.011	0.010	0.008	0.008	0.012	<0.005	0.010	0.008	0.006	0.010
Zn	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

(continued)

Note: ND = Not determined.

TABLE 32 (continued)

Boring and sample	2C3	2C4	2C5	2C6	3C1	3C2	3C3	3C4	3C5	3C6
Elevation (m)	2.01	1.10	-0.12	-1.04	5.14	3.61	1.98	1.07	-0.15	-1.07
Depth below sludge/soil interface (m)	0.11	1.02	2.24	3.16	-3.05	-1.52	0.11	1.02	2.24	3.16
Ht. above water table (m)	0.87	-0.04	-1.26	-2.18	6.10	4.57	2.94	2.03	0.81	-0.11
Conc. (mg/ℓ)										
SO_4	45	<8	<8	<8	116	135	47	<8	<8	<8
SO_3	<1	<1	<1	<1	<1	50	<1	<1	<1	<1
Cl	30	45	55	70	30	40	90	125	130	75
NO_3-N	0.03	0.05	0.04	0.12	0.09	0.30	0.06	0.09	0.07	0.04
NO_2-N	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
CN^-	<0.01	<0.01	<0.01	<0.01	0.02	0.25	0.01	<0.01	<0.01	<0.01
TOC	13	13	8	42	24	1240	10	12	11	8
Phenol	0.01	<0.01	<0.01	<0.01	0.01	2.04	<0.01	<0.01	<0.01	<0.01
Ca	6.90	3.40	4.60	8.40	38.80	34.80	12.60	6.60	8.30	6.90
Fe	0.129	0.143	0.123	ND	ND	ND	ND	ND	ND	ND
K	0.61	0.82	0.81	0.35	1.02	12.90	0.24	0.38	0.35	0.38
Mg	2.22	1.38	1.70	2.18	8.94	ND	4.66	2.86	3.23	2.50
Mn	0.008	0.013	0.012	0.004	0.085	0.002	0.016	0.005	0.004	0.004
Na	79.70	74.10	69.60	70.80	60.60	298.00	125.00	126.00	124.00	87.00
As	<0.003	<0.003	0.011	<0.003	<0.003	0.080	<0.003	<0.003	<0.003	<0.003
B	0.17	0.20	0.06	<0.02	0.03	0.06	0.17	0.22	0.15	0.04
Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd	0.0009	0.0003	0.0003	0.0003	0.0009	0.0010	0.0011	<0.0003	<0.0003	<0.0003
Cr	0.007	0.011	0.008	0.003	0.007	0.011	0.003	0.003	<0.003	0.003
Cu	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hg	0.0003	0.0004	<0.0002	0.0004	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	<0.0002
Ni	<0.005	<0.005	<0.005	0.005	0.005	0.049	<0.005	<0.005	<0.005	<0.005
Pb	0.006	0.005	0.003	0.002	0.012	0.039	<0.002	0.004	0.003	<0.002
Se	0.010	<0.005	0.008	0.008	0.006	0.012	<0.005	<0.005	<0.005	0.006
Zn	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 33. RESULTS OF RANDOMIZATION TEST OF DISTILLED WATER EXTRACTS OF SOIL SAMPLES DIRECTLY UNDER THE DISPOSAL SITES AND AT COMPARABLE ELEVATIONS OUTSIDE THE DISPOSAL SITE

	W	X	Y	Z
SO_4	NS	S	NS	NS
SO_3	S	NS	NP	NP
Cl	S	NS	S	NS
NO_3-N	NS	NS	NS	NS
NO_2-N	S	S	NS	NP
CN	NP	NS	S	NP
TOC	NS	S	NP	NS
Phenol	ND	ND	ND	S
Ca	SS	NS	NS	NS
Fe	NP	S	NS	NP
K	ND	ND	S	NS
Mg	NS	NS	NS	NS
Mn	ND	S	NP	NS
Na	S	S	S	NS
As	S	S	NS	NS
B	NS	NS	S	NS
Be	NP	S	NP	NP
Cd	S	S	NS	S
Cr	S	NS	NS	S
Cu	S	NP	NP	ND
Hg	NS	S	NS	NS
Ni	S	S	NS	NS
Pb	S	S	NS	NS
Se	S	NS	NP	NS
Zn	S	S	NS	ND

S = Concentration of constituent significantly larger under the disposal site at a 90% level of significance.

SS = Significantly small

NS = Concentration of constituent not significantly larger or smaller under the disposal site at a 90% level of significance.

ND = Not determined.

NP = Not possible to test statistically; too few data points.

water. The magnitude of any potential pollution problem depends on the amount of removal that can be produced by soils below the waste and the amount of dilution that occurs as the leachate leaves the site.

REFERENCES

1. U. S. Environmental Protection Agency, Everybody's Problem: Hazardous Wastes, Publ. No. SW-826, U. S. Environmental Protection Agency, Washington, D.C., 1980. 36 pp.

2. Anonymous, Industrial Dumps Threaten Groundwater, Engineering News-Record, 6 October 1977, p. 69.

3. Deutsch, M., Phenol Contamination of an Artesian Glacial-Drift Aquifer at Alma, Michigan, U.S.A. Proceedings Society Water Treatment and Examination, 11(2):94-100, 1962.

4. Miller, D. W., DeLuca, F. A., and Tessier, T. L., Groundwater Contamination in the Northeastern States, EPA-660-2-74-056, Environmental Protection Agency, Washington, D.C., 1974. 287 pp.

5. Environmental Effects Laboratory, U.S. Army Engineer Waterways Experiment Station, Chemical and Physical Effects of Municipal Landfills on Underlying Soils and Groundwater, EPA-600/2-78-096, U. S. Environmental Protection Agency, Cincinnati, OH, 1978. 154 pp.

6. Malone, P. G. and Jones, L.W., The Effects of Flue Gas Cleaning Waste on Groundwater Quality and Soil Characteristics, USEPA Publ., EPA-600/2-79-164, U. S. Environmental Portection Agency, Cincinnati, OH, 1979. 129 pp.

7. Mercer, R. B., Malone, P. G., and Groughton, J. D., Field Evaluation of Chemically Stabilized Sludges. In: Land Disposal of Hazardous Wastes, David Shultz ed. EPA-600/9-78-016, U. S. Environmental Protection Agency, Cincinnati, Ohio, 1978. pp. 357-365.

8. Jones, L. W., Malone, P. G. and Myers, T. E., Field Investigation of Contaminant Loss from Chemically Stabilized Sludges, Disposal of Hazardous Wastes, David Schultz ed., EPA-600/0-80-0010, U. S. Environmental Protection Agency, Cincinnati, OH, 1980. pp. 187-202.

9. U. S. Army Engineer Waterways Experiment Station, The Unified Soil Classification System, Tech. Memorandum No. 3-257, Vol. 1, USAE Waterways Experiment Station, Vicksburg, MS, 1960. 30 pp.

10. Foster, J. R. The Reduction of Matrix Effects in Atomic Absorption Analysis and the Efficiency of Selected Extractions on Rock Forming Minerals. In: Geochemical Exploration, The Canadian Institute of Mining and Metallurgy. Special Vol. 11, Ottawa, Canada, 1971. pp. 554-560.

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11. Griffin, R. A. et al., Attentuation of Pollutants in Landfill Leachate by Clay Materials, Environmental Geology Notes No. 78, Illinois Geological Survey, Urbana, IL, 1976. 34 pp.

12. Siegel, Sidney, Nonparametric Statistics for the Behavorial Sciences, McGraw-Hill Book Co., New York, NY, 1956. 312 pp.

13. Connor, J. J. and Shacklette, H. T., Background Geochemistry of Some Rocks, Soils, Plants, and Vegetables in the Coterminous United States. U. S. Geol. Surv. Prof. Paper 574-F, U. S. Gov. Printing Office, Washington, D. C., 1975. 186 pp.

14. U. S. Environmental Protection Agency, Quality Criteria for Water, EPA-440/9-76-023, U. S. Environmental Protection Agency, Washington, D. C., 1976. 501 pp.

APPENDIX

TABLE A-1. LOG OF BORING 1 AT SITE W

Elevation above MSL* (m)	Depth (m)	Description
258.93 - 255.88	0.00 - 3.05	Industrial waste, red and black
255.88 - 250.70	3.05 - 8.23	Clay (CL), light brown and gray, trace of gravel
250.70 - 250.32	8.23 - 8.61	Sandy, silty clay (CL), dark gray, with small gravel

*MSL = mean sea level

Elevation of water table = 253.32 msl.

TABLE A-2. LOG OF BORING 2 AT SITE W

Elevation above MSL* (m)	Depth (m)	Description
257.74 - 256.52	0.00 - 1.22	Industrial waste, red and black
256.52 - 255.61	1.22 - 2.13	Clay (CL), gray
255.61 - 251.19	2.13 - 6.55	Clay (CL), light tan and light gray with silt and occasional sand
251.19 - 251.13	6.55 - 6.61	Silty sand (SM), gray
251.13 - 251.06	6.61 - 6.68	Clay (CL), gray
251.06 - 250.76	6.68 - 6.98	Gravelly clay (CL), gray

*MSL = mean sea level

Elevation of water table = 252.31 msl.

TABLE A-3. LOG OF BORING 3 AT SITE W

Elevation above MSL* (m)	Depth (m)	Description
256.87 - 255.96	0.00 - 0.91	Silty clay (CL), dark brown
255.96 - 253.70	0.91 - 3.17	Clay (CL), light and dark tan with fine to coarse sand and silt, trace of small gravel
253.70 - 253.61	3.17 - 3.26	Silty sand (SM), light brown, fine
253.61 - 253.52	3.26 - 3.35	Clay (CL), light brown with silt and small gravel
253.52 - 251.23	3.35 - 5.64	Clay (CL), gray with silt and small gravel
251.23 - 249.40	5.64 - 7.47	Clay (CL), gray with silt, small gravel and fine to coarse light brown sand pockets
249.40 - 248.64	7.47 - 8.23	Clay (CL), gray with silt, sand, and small gravel

*MSL = mean sea level

Elevation of water table = 250.62 msl.

TABLE A-4. LOG OF BORING 4 AT SITE W

Elevation above MSL* (m)	Depth (m)	Description
256.74 - 254.61	0.00 - 2.13	Clayey silt (ML), dark gray and light brown
254.61 - 253.08	2.13 - 3.66	Clay (CL), light brown with gray pockets with silt, trace of small gravel
253.08 - 251.25	3.66 - 5.49	Clay (CL), gray with silt and fine to coarse sand, trace of small gravel
251.25 - 250.45	5.49 - 6.29	Silty sand (SM), gray, fine, wet

*MSL = mean sea level

Elevation of water table = 251.71 msl.

TABLE A-5. LOG OF BORING 5 AT SITE W

Elevation above MSL* (m)	Depth (m)	Description
256.87 - 255.65	0.00 - 1.22	Silty clay (CL), light brown with coarse sand and small gravel
255.65 - 254.74	1.22 - 2.13	Silty clay (CL), gray with light brown with small gravel
254.74 - 253.82	2.13 - 3.05	Silty clay (CL), light brown and gray
253.82 - 251.48	3.05 - 5.39	Silty clay (CL), light brown and gray with coarse sand, trace of small gravel
251.48 - 250.74	5.39 - 6.13	Silty clay (CL), light brown with coarse sand, moist
250.74 - 250.50	6.13 - 6.37	Silty sand (SM), brown, fine to coarse, wet
250.50 - 249.07	6.37 - 7.80	Clay (CL), gray with silt

*MSL = mean sea level

Elevation of water table = 250.87 msl.

TABLE A-6. LOG OF BORING 6 AT SITE W

Elevation above MSL* (m)	Depth (m)	Description
257.30 - 257.09	0.00 - 0.21	Road bed
257.09 - 256.39	0.21 - 0.91	Fill, black, clay, silt, sand, gravel, cobbles
256.39 - 256.17	0.91 - 1.13	Silty clay (CL), light brown with coarse sand, occasional small gravel
256.17 - 255.17	1.13 - 2.13	Silty clay (CL), dark tan, trace of small gravel, wet
255.17 - 254.25	2.13 - 3.05	Silty clay (CL), dark tan, trace of small gravel, wet
254.25 - 252.73	3.05 - 4.57	Silty clay (CL), dark tan with gray spots with coarse sand, dry
252.73 - 251.97	4.57 - 5.33	Sandy, silty clay (CL), light brown with small gravel

*MSL = mean sea level

Elevation of water table = 254.68 msl.

TABLE A-7. LOG OF BORING 7 AT SITE W

Elevation above MSL* (m)	Depth (m)	Description
256.13 - 255.98	0.00 - 0.15	Road, gravel
255.98 - 255.06	0.15 - 1.07	Clay (CL), dark brown with silt
255.06 - 254.30	1.07 - 1.83	Clay (CL), light brown and light gray with silt, trace of small and large gravel
254.30 - 253.08	1.83 - 3.05	Clay (CL), light brown and light gray with silt and coarse sand, trace of small and large gravel
253.08 - 251.56	3.05 - 4.57	Sandy, silty clay (CL), light brown, trace of gravel, damp
251.56 - 251.47	4.57 - 4.66	Sand (SP), brown, wet
251.47 - 251.10	4.66 - 5.03	Clay (CL), gray

*MSL = mean sea level

Elevation of water table = 253.08 msl.

TABLE A-8. LOG OF BORING 8 AT SITE W

Elevation above MSL* (m)	Depth (m)	Description
256.66 - 256.36	0.00 - 0.30	Fill, dark brown, silty clay with occasional sticks
256.36 - 255.75	0.30 - 0.91	Fill, light gray, silty clay
255.75 - 254.83	0.91 - 1.83	Silty clay (CL), dark and light brown
254.83 - 253.61	1.83 - 3.05	Sandy, silty clay (CL), dark and light brown
253.61 - 252.09	3.05 - 4.57	Silty clay (CL), gray with small gravel
252.09 - 250.56	4.57 - 6.10	Sandy, silty clay (CL-ML), gray with small gravel, moist
250.56 - 248.96	6.10 - 7.70	Sandy, silty clay (CL-ML), gray with small gravel, dry

*MSL = mean sea level

Elevation of water table = 251.81 msl.

TABLE A-9. LOG OF BORING 1 AT SITE X

Elevation above MSL* (m)	Depth (m)	Description
286.25 - 285.34	0.00 - 0.91	Fill, gray
285.34 - 284.42	0.91 - 1.83	Clay (CL), reddish brown with fine sand
284.42 - 283.51	1.83 - 2.74	Gravel (GP), small to large
283.51 - 282.29	2.74 - 3.96	Gravelly clay (GC), small to large

*MSL = mean sea level

Elevation of water table = 283.42 msl.

TABLE A-10. LOG OF BORING 2 AT SITE X

Elevation above MSL* (m)	Depth (m)	Description
286.55 - 285.33	0.00 - 1.22	Fill, gray
285.33 - 284.57	1.22 - 1.98	Clay (CL), reddish brown with sand and gravel
284.57 - 281.67	1.98 - 4.88	Gravelly clay (GC)

*MSL = mean sea level

Elevation of water table = 283.62 msl.

TABLE A-11. LOG OF BORING 3 AT SITE X

Elevation above MSL* (m)	Depth (m)	Description
285.37 - 284.03	0.00 - 1.34	Clay (CL), reddish brown with sand and traces of gravel
284.03 - 282.17	1.34 - 3.20	Sandy clay (CL), reddish brown with gravel
282.17 - 281.10	3.20 - 4.27	Gravelly clay (GC)

*MSL = mean sea level

Elevation of water table = 283.19 msl.

TABLE A-12. LOG OF BORING 4 AT SITE X

Elevation above MSL* (m)	Depth (m)	Description
285.46 - 284.85	0.00 - 0.61	Sandy clay (CL), reddish brown, trace of gravel
284.85 - 281.50	0.61 - 3.96	Gravel (GP), small to large with clay
281.50 - 281.19	3.96 - 4.27	Clay (CH), wet

*MSL = mean sea level

Elevation of water table = 283.29 msl.

TABLE A-13. LOG OF BORING 5 AT SITE X

Elevation above MSL* (m)	Depth (m)	Description
285.85 - 284.94	0.00 - 0.91	Clay (CL), reddish brown with sand
284.94 - 284.63	0.91 - 1.22	Sandy, gravelly clay (GC), reddish brown
284.63 - 281.89	1.22 - 3.96	Gravel (GP), small to large
281.89 - 281.37	3.96 - 4.48	Clay (CL), wet

*MSL = mean sea level

Elevation of water table = 283.30 msl.

Table 18. Effect of carbophenothion on fecundity of grass shrimp (Palaemonetes pugio). The three components of fecundity examined included total number of ovigerous females, average egg production and hatching success in each test concentration. The number of eggs produced per female was determined for at least 10 shrimp per test concentration. Using a separate group of shrimp, hatching success was determined for each test concentration. Since egg production is proportional to length of female, rostrum-telson length of each female was used as a covariate in all statistical analyses.

Measured concentration (µg/ℓ)	Total No. ovigerous females	Average egg production (eggs/♀)	Average female length (mm)	Average No. larvae hatched/♀	Average female length (mm)
Control	45	154.5	26.8	125.1	27.1
Carrier control	40	154.6	27.4	115.1	29.2
0.06	46	132.9	26.6	118.1	28.0
0.22	50	157.4	26.6	94.7	26.6
0.36	30[a]	154.1	26.9	142.8	30.9
0.69	29[a]	163.3	27.1	164.4	29.7
1.3	32[a]	156.0	27.1	120.2	29.4
2.9	6[a,b]	-[c]	-	125	28.5

[a]Significantly less than the controls by Day 147.
[b]Significantly less than the controls by Day 84.
[c]Egg production not determined for this concentration.

Table 19. Survival of F_1 generation grass shrimp (Palaemonetes pugio) larvae reared under conditions of continued exposure to carbophenothion. Each larval rearing trial was run with larvae produced by a single female.

Concentration (µg/ℓ)	Number of larval rearing trials	Average survival from hatching to Day 10, %	Range
Control	10	90	46-100
Carrier control	16	82	50-100
0.06	14	83	36-100
0.22	12	83	63-97
0.36	13	82	43-100
0.69	14	85	67-100
1.3	7	84	70-97
2.9	5	5[a]	0-26[a]

[a]Significantly different from survival of controls ($\alpha = 0.05$).

TABLE A-14. LOG OF BORING 6 AT SITE X

Elevation above MSL* (m)	Depth (m)	Description
285.60 - 284.69	0.00 - 0.91	Silty clay (CL), brown
284.69 - 283.77	0.91 - 1.83	Sandy, silty clay (CL), reddish brown with gravel
283.77 - 282.25	1.83 - 3.35	Gravel (GP)

*MSL = mean sea level

Elevation of water table = 283.31 msl.

TABLE A-15. LOG OF BORING 7 AT SITE X

Elevation above MSL* (m)	Depth (m)	Description
285.52 - 285.49	0.00 - 0.03	Silty clay (CL)
285.49 - 285.43	0.03 - 0.09	Coal fragments
285.43 - 284.61	0.09 - 1.91	Sandy, silty clay (CL), brown
284.61 - 285.54	1.91 - 1.98	Sandy, silty clay (CL), reddish brown with gravel
283.54 - 281.56	1.98 - 3.96	Gravel (GP)
281.56 - 281.04	3.96 - 4.48	Clay (CL), wet

*MSL = mean sea level

Elevation of water table = 283.23 msl.

TABLE A-16. LOG OF BORING 8 AT SITE X

Elevation above MSL* (m)	Depth (m)	Description
285.57 - 284.75	0.00 - 0.82	Silty clay (CL), reddish brown with gravel
284.75 - 281.52	0.82 - 4.05	Gravel (GP), small to large

*MSL = mean sea level

Elevation of water table = 283.28 msl.

TABLE A-17. LOG OF BORING 9 AT SITE X

Elevation above MSL* (m)	Depth (m)	Description
285.20 - 284.50	0.00 - 0.70	Silty clay (CL), reddish brown with gravel
284.50 - 282.24	0.70 - 2.96	Gravel (GP), small to large

*MSL = mean sea level

Elevation of water table = 283.01 msl.

TABLE A-18. LOG OF BORING 1 AT SITE Y

Elevation above MSL* (m)	Depth (m)	Description
186.61 - 185.70	0.00 - 0.91	Silty clay (CL), light brown with coarse sand
185.70 - 185.24	0.91 - 1.37	Clay (CL), light brown and dark brown with fine to coarse black sand pockets
185.24 - 184.78	1.37 - 1.83	Silty sand (SM), gray and brown, fine, wet
184.78 - 184.48	1.83 - 2.13	Clay (CL), dark brown and gray, dry

*MSL = mean sea level

Elevation of water table = 185.15 msl.

TABLE A-19. LOG OF BORING 2 AT SITE Y

Elevation above MSL* (m)	Depth (m)	Description
186.88 - 186.58	0.00 - 0.30	Clay (CL), dark and light brown with silt
186.58 - 185.51	0.30 - 1.37	Silty sand (SM), fine, gray and light brown
185.51 - 185.20	1.37 - 1.68	Clay (CL), gray
185.20 - 183.83	1.68 - 3.05	Silty clay (CL), brown
183.83 - 181.39	3.05 - 5.49	Sandy silty clay (CL), dark gray and light brown with thin lenses of fine sand
181.39 - 179.26	5.49 - 7.62	Silty sand (SM), fine, dark tan
179.26 - 177.13	7.62 - 9.75	Silty sand (SM), fine, dark and light tan
177.13 - 176.33	9.75 - 10.55	Silty sand (SM), fine to coarse, dark gray, wet

*MSL = mean sea level

Elevation of water table = 177.13 msl.

TABLE A-20. LOG OF BORING 3 AT SITE Y

Elevation above MSL* (m)	Depth (m)	Description
186.98 - 186.07	0.00 - 0.91	Sandy silty clay (CL), dark brown with gravel
186.07 - 184.14	0.91 - 2.84	Clay (CL), dark and light brown
184.14 - 183.99	2.84 - 2.99	Silty sand (SM), fine, light brown, damp
183.99 - 181.28	2.99 - 5.70	Clay (CL), light brown with small sand pockets
181.28 - 179.27	5.70 - 7.71	Silty sand (SM), fine, light brown and dark gray
179.27 - 177.23	7.71 - 9.75	Gravelly clay (GC)
177.23 - 176.31	9.75 - 10.67	Sand (SP), fine to coarse, dark gray with clay and small to large gravel

*MSL = mean sea level

Elevation of water table = 177.07 msl.

TABLE A-21. LOG OF BORING 4 AT SITE Y

Elevation above MSL* (m)	Depth (m)	Description
186.95 - 186.04	0.00 - 0.91	Clay (CL), light and dark tan with silt and coarse sand, black spots
186.04 - 185.88	0.91 - 1.07	Clayey silty sand (SM), fine, light and dark tan
185.88 - 185.27	1.07 - 1.68	Silty sand (SM), fine, light and dark tan with occasional cobbles
185.27 - 183.90	1.68 - 3.05	Clay (CL), light brown with silt
183.90 - 181.10	3.05 - 5.85	Clay (CL), dark gray with silt, coarse sand and trace of small gravel
181.10 - 177.20	5.85 - 9.75	Sand (SP), fine, light gray with silt
177.20 - 176.43	9.75 - 10.52	Sand (SP), fine, gray with silt

*MSL = mean sea level

Elevation of water table = 177.35 msl.

TABLE A-22. LOG OF BORING 5 AT SITE Y

Elevation above MSL* (m)	Depth (m)	Description
186.67 - 185.76	0.00 - 0.91	Silty clay (CL), dark tan and dark brown, trace of small gravel
185.76 - 185.15	0.91 - 1.52	Silty sand (SM), fine, dark and light tan
185.15 - 184.54	1.52 - 2.13	Silty sand (SM), fine, dark and light tan, wet
184.54 - 183.62	2.13 - 3.05	Silty sand (SM), fine, dark and light tan, damp
183.62 - 179.05	3.05 - 7.62	Silty sand (SM), fine to coarse, dark brown
179.05 - 176.92	7.62 - 9.75	Silty sand (SM), fine, dark tan
176.92 - 176.18	9.75 - 10.49	Silty sand (SM), fine to coarse, dark tan, wet

*MSL = mean sea level

Elevation of water table = 176.86 msl.

TABLE A-23. LOG OF BORING 6 AT SITE Y

Elevation above MSL* (m)	Depth (m)	Description
186.78 - 186.48	0.00 - 0.30	Silty clay (CL), dark brown
186.48 - 185.10	0.30 - 1.68	Silty sand (SM), fine, dark and light tan
185.10 - 181.29	1.68 - 5.49	Clay (CL), dark and light tan with sand layers
181.29 - 179.16	5.49 - 7.62	Silty sand (SM), fine, dark tan
179.16 - 176.26	7.62 - 10.52	Silty sand (SM), fine to coarse, dark tan, trace of small gravel

*MSL = mean sea level

Elevation of water table = 176.90 msl.

TABLE A-24. LOG OF BORING 7 AT SITE Y

Elevation above MSL* (m)	Depth (m)	Description
186.86 - 185.95	0.00 - 0.91	Silty clay (CL), light and dark brown
185.95 - 183.81	0.91 - 3.05	Silty sand (SM), fine, light and dark tan
183.81 - 181.37	3.05 - 5.49	Sand (SP), fine with silt, wet
181.37 - 179.85	5.49 - 7.01	Silty sand (SM), fine, dark tan, damp
179.85 - 178.93	7.01 - 7.93	Gravelly clay (GC)
178.93 - 176.28	7.93 - 10.58	Silty sand (SM), fine to coarse, light brown, trace of small gravel, wet

*MSL = mean sea level

Elevation of water table = 179.03 msl.

TABLE A-25. LOG OF BORING 8 AT SITE Y

Elevation above MSL* (m)	Depth (m)	Description
186.57 - 186.27	0.00 - 0.30	Silty clay (CL), light brown
186.27 - 185.05	0.30 - 1.52	Silty sand (SM), fine, dark tan
185.05 - 183.52	1.52 - 3.05	Silty sand (SM), fine to coarse, dark brown
183.52 - 181.08	3.05 - 5.49	Silty sand (SM), fine, dark tan
181.08 - 178.95	5.49 - 7.62	Silty sand (SM), fine to medium, light brown
178.95 - 178.71	7.62 - 7.86	Silty sand (SM), fine to medium, dark brown
178.71 - 177.12	7.86 - 9.45	Silty sand (SM), fine, light brown
177.12 - 176.36	9.45 - 10.21	Silty sand (SM), fine dark gray, wet

*MSL = mean sea level

Elevation of water table = 177.49 msl.

TABLE A-26. LOG OF BORING 9 AT SITE Y

Elevation above MSL* (m)	Depth (m)	Description
186.70 - 185.79	0.00 - 0.91	Silty clay (CL), light and dark tan with small pockets of fine white sand
185.79 - 185.02	0.91 - 1.68	Silty sand (SM), fine, light and dark tan
185.02 - 179.08	1.68 - 7.62	Clay (CL), light brown and dark gray with silt, coarse sand, and small gravel
179.08 - 177.40	7.62 - 9.30	Sand (SP) with clay layers
177.40 - 175.27	9.30 - 11.43	Sand (SP), wet
175.27 - 174.66	11.43 - 12.04	Clay (CL)

*MSL = mean sea level

Elevation of water table = 176.95 msl.

TABLE A-27. LOG OF BORING 1 AT SITE Z

Elevation above MSL* (m)	Depth	Description
5.76 - 2.56	0.00 - 3.20	Mixture of cover material (gray clay) and fill grading to black, oily, wet fill
2.56 - 2.10	3.20 - 3.66	Clay (CH), dark tan
2.10 - (-) 1.25	3.66 - 7.01	Clay (CH), red with gray mottles
(-) 1.25 - (-) 2.77	7.01 - 8.53	Clay (CH), Greenish gray with pockets of fine to medium sand
(-) 2.77 - (-) 4.24	8.53 - 10.00	Silt (ML), mottled gray and dark tan with black inclusions

*MSL = mean sea level

Elevation of water table above msl = 1.34

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TABLE A-28. LOG OF BORING 2 AT SITE Z

Elevation above MSL* (m)	Depth	Description
5.32 - 4.86	0.00 - 0.46	Clay (CH) with limestone fragments and fill
4.86 - 2.12	0.46 - 3.20	Fill, black, oily, wet
2.12 - 1.36	3.20 - 3.96	Clay (CH), red and gray
1.36 - 0.29	3.96 - 5.03	Clay (CH), mottled red and gray with calcareous nodules
0.29 - (-) 0.93	5.03 - 6.25	Clay (CH), mottled red and gray with calcareous nodules and black inclusions
(-) 0.93 - (-) 1.66	6.25 - 9.98	Clay (CH), greenish gray with calcareous nodules

*MSL = mean sea level

Elevation of water table above msl = 1.17

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TABLE A-29. LOG OF BORING 3 AT SITE Z

Elevation above MSL* (m)	Depth	Description
5.29 - 2.09	0.00 - 3.20	Fill, black, oily, wet surface metre mixed with clay cover
2.09 - 0.41	3.20 - 4.88	Clay (CH), mottled red and gray, wet
0.41 - (-) 0.81	4.88 - 6.10	Clay (CH), mottled red and gray with calcareous nodules
(-) 0.81 - (-) 1.63	6.10 - 6.92	Clay (CH), greenish gray with calcareous nodules

*MSL = mean sea level

Elevation of water table above msl = 1.33

TABLE A-30. LOG OF BORING 4 AT SITE Z

Elevation above MSL* (m)	Depth	Description
4.54 - 2.71	0.00 - 1.83	Clay (CH), dark gray
2.71 - 1.34	1.83 - 3.20	Clay (CH), mottled red and gray
1.34 - (-) 0.95	3.20 - 5.49	Clay (CH), mottled red and gray with calcareous nodules
(-) 0.95 - (-) 2.78	5.49 - 7.32	Clay (CH), greenish gray with calcareous nodule to 3 cm diameter
(-) 2.78 - (-) 3.20	7.32 - 7.74	Silty clay (CH), mottled greenish gray and dark tan with calcareous nodules to 3 cm diameter

*MSL = mean sea level

Elevation of water table above msl = 1.34

TABLE A-31. LOG OF BORING 5 AT SITE Z

Elevation above MSL* (m)	Depth	Description
4.70 - 2.57	0.00 - 2.13	Clay (CH), dark gray with traces of fill
2.57 - (-) 0.63	2.13 - 5.33	Clay (CH), mottled red and gray
(-) 0.63 - (-) 2.01	5.33 - 6.71	Clay (CH), greenish gray with red mottles and scattered black inclusions
(-) 2.01 - (-) 3.01	6.71 - 7.71	Silty clay (CL) mottled greenish gray and dark tan with calcareous nodules to 1 cm diameter

*MSL = mean sea level

Elevation of water table above msl = 1.16

TABLE A-32. LOG OF BORING 6 AT SITE Z

Elevation above MSL* (m)	Depth	Description
5.21 - 3.08	0.0 - 2.13	Fill, black
3.08 - 1.40	2.13 - 3.81	Clay (CH), mottled red and gray, wet
1.40 - (-) 0.88	3.81 - 6.10	Clay (CH), mottled red and gray with calcareous nodules
(-) 0.88 - (-) 2.10	6.10 - 7.32	Clay (CH), greenish gray
(-) 2.10 - (-) 3.63	7.32 - 8.84	Clay (CH), greenish gray with dark tan mottles and black inclusions
(-) 3.63 - (-) 4.51	8.84 - 9.72	Silty clay (CL), mottled greenish gray and dark tan with calcareous nodules and black inclusions

*MSL = mean sea level

Elevation of water table above msl = 1.13

TABLE A-33. LOG OF BORING 7 AT SITE Z

Elevation above MSL* (m)	Depth	Description
5.14 - 3.31	0.00 - 1.83	Fill, black
3.31 - 2.40	1.83 - 2.74	Clay (CH), green, disturbed
2.40 - 1.33	2.74 - 3.81	Clay (CH), mottled red and gray
1.33 - (-) 0.96	3.81 - 6.10	Clay (CL), mottled red and gray with calcareous nodules
(-) 0.96 - (-) 3.21	6.10 - 8.35	Clay (CH), greenish gray with calcareous nodules

*MSL = mean sea level

Elevation of water table above msl = 1.02

TABLE A-34. LOG OF BORING 8 AT SITE Z

Elevation above MSL* (m)	Depth	Description
1.87 - 1.57	0.00 - 0.30	Clay (CH), gray with shells (road metal)
1.57 - 0.80	0.30 - 1.07	Clay (CH), gray
0.80 - 0.04	1.07 - 1.83	Clay (CH), red
0.04 - (-) 1.64	1.83 - 3.51	Clay (CH), mottled greenish gray and tan
(-) 1.64 - (-) 2.79	3.51 - 4.66	Clay (CH), mottled red and gray with calcareous nodules to 1 cm diameter
(-) 2.79 - (-) 3.46	4.66 - 5.33	Silty clay (CL), mottled greenish gray and dark tan with calcareous nodules

*MSL = mean sea level

Elevation of water table above msl = 0.84

TABLE A-35. LOG OF BORING 9 AT SITE Z

Elevation above MSL* (m)	Depth	Description
7.62 - 7.16	0.00 - 0.46	Road base, gravel and clay
7.16 - 6.40	0.46 - 1.22	Clay (CH), gray (fill)
6.40 - 3.05	1.22 - 4.57	Clay (CH), greenish gray and red (fill)
3.05 - 0.30	4.57 - 7.32	Clay (CH), dark gray, red, gray (fill)
0.30 - (-) 1.22	7.32 - 8.84	Clay (CH), dark gray with shell fragments
(-) 1.22 - (-) 2.13	8.84 - 9.75	Clay (CH), gray
(-) 2.13 - (-) 2.44	9.75 - 10.06	Clay (CH), mottled dark tan and gray
(-) 2.44 - (-) 3.14	10.06 - 10.76	Silty clay (CH), mottled dark gray and tan with calcareous nodules to 1 cm diameter

*MSL = mean sea level

Elevation of water table above msl = 0.94

TABLE A-36. LOG OF BORING 10 AT SITE Z

Elevation above MSL* (m)	Depth	Description
3.96 - 2.13	0.00 - 1.83	Clay (CH), dark gray
2.13 - 1.22	1.83 - 2.74	Clay (CH), mottled red and gray
1.22 - 0.30	2.74 - 3.66	Clay (CH), mottled red and gray with calcareous nodules
0.30 - (-) 0.92	3.66 - 4.88	Clay (CH), red with calcareous nodules
(-) 0.92 - (-) 1.56	4.88 - 5.52	Clay (CH), greenish gray

*MSL = mean sea level

Elevation of water level above msl = 1.25